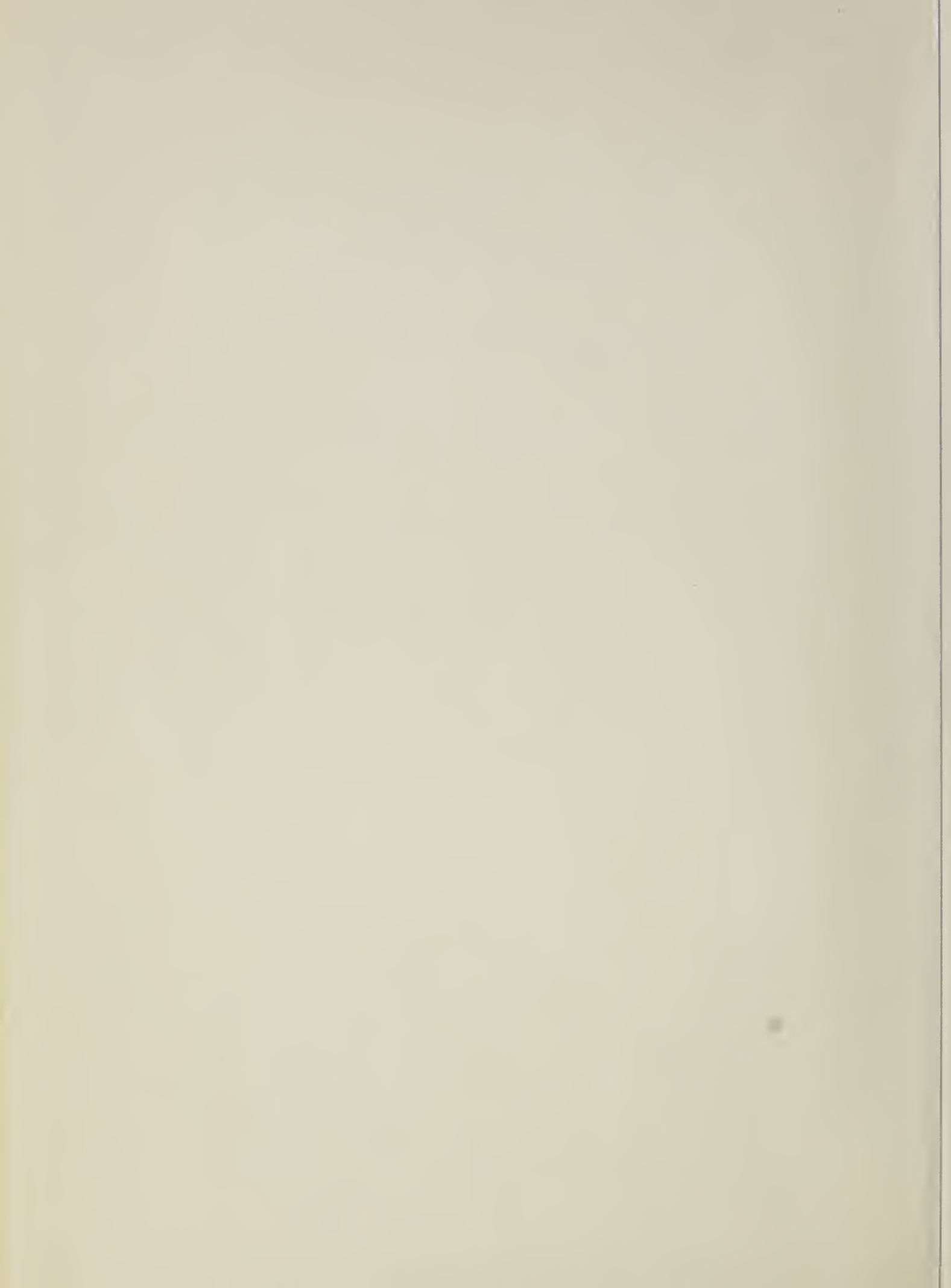


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A Summary of Current Program, 10/15/62

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AGRICULTURAL ENGINEERING RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

There is included under each problem area in the report a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research. Also included is a brief description of related work conducted by private organizations. No details on progress of State station or industry research are included except as such work is cooperative with U.S.D.A.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued between April 1, 1960, and March 31, 1962. Current agricultural research findings are also published in the Monthly U.S.D.A. publication, Agricultural Research. This progress report was compiled in the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
October 15, 1962

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INTRODUCTION

Agricultural Engineering Research as used in this report is concerned with the applications of engineering principles to agricultural production and rural living. More specifically, it deals with the power, machines and structures required, and includes (a) development of new and improved equipment for the more effective mechanization of seedbed preparation, fertilization, planting, cultivation, pesticide application, harvesting and farm handling of crops, and studies of the more efficient use of such equipment; (b) development of more effective and lower cost buildings and equipment for the handling and sheltering of livestock, including research in functional requirements; for the handling and storing of farm commodities on the farm, and for farm living; (c) development of more effective methods and equipment for the mechanical preparation and conditioning of farm products for farm use or sale, including such testing and quality determination as needed to adequately evaluate research results, and (d) adaptation and development of methods and equipment for effective and economical farm and rural applications of electric energy, used as power, heat, light and other electromagnetic radiations for plant and animal production, farm processing and rural living.

The importance of Agricultural Engineering research to the nation's agriculture is shown by the fact that power, machines and structures with which it is concerned are essential facilities for every one of more than 3.7 million farms on which equipment and buildings valued at over 45 billion dollars are used to produce and handle about 600 million tons of crop and animal products each year. Also, the solutions of most plant and animal production problems are in part determined by the machines and structures available and likewise almost every new finding in soil, plant, or animal science research requires additional engineering research for its most effective implementation. As the relative cost of labor increases and the mechanization of agricultural operations progresses, engineering research becomes increasingly important. Since the close of World War II the annual man-hours of farm labor has been reduced about 37 percent, from 17.4 billion to 11.0 billion, the number of tractors has more than doubled, from about 2.5 million to more than 5 million, and the percent of farms served by electric power lines has also doubled from about 48 to over 96. Each farm worker has available between 30 and 40 mechanical and electric horsepower. The investment per worker for land and other facilities, which is higher than for all manufacturing, averages over \$22,000. For many commercial farms it is more than twice as great and for certain types of farms over large areas it is \$100,000 or more.

The following examples are illustrative of research accomplishments for which the Agricultural Engineering Research Division (AERD) has had a major responsibility:

(1) Determining the effects of methods of manufacture and steel specifications on the service of disks used on agricultural implements. Disks are one of the most common components of tillage tools. Improvements in them affect nearly every farmer. Laboratory tests were made with equipment developed by AERD to find the effect on length of service of design factors including alloy used and methods of rolling and sharpening. It was found, for example, that cross rolling the steel and initial sharpening by hot edge rolling rather than grinding both considerably increased the impact and fatigue resistance. As a result of this research, cross rolled steel and roll sharpening are now being used by the largest manufacturer of agricultural disks.

(2) One result of research in cotton ginning is efficient equipment for removing sticks and stems from machine- and rough hand-harvested seed cotton. Cylinders made of saws, one below the other, are used and operated in conjunction with horizontal grid bar concaves. Trash is slung off through the restraining grid bars by centrifugal force and brushes doff the seed cotton.

A working model of the cleaner was tested and demonstrated in 1953 on machine stripped cotton, and by 1956 all the leading gin machine manufacturers were producing the machine either in the original form or were otherwise employing the principle. The new cleaner cost less than equipment formerly used to perform approximately the same job but with less efficiency. There is also a grade improvement benefit. The estimated dollar value of this development is \$20,000,000 annually.

(3) In cooperation with Michigan State University, equipment and methods have recently been devised to reduce labor requirements and costs for harvesting tart cherries. Hydraulically activated shakers remove 95 percent of the cherries from trees. Remaining cherries are mainly undersized and lack maturity. Several types of portable frames catch the cherries. In 1962, 30 growers used this harvesting equipment in conjunction with the previously developed water handling and transport system. Rates of 4,000 pounds per hour and as high as 23 trees per hour were obtained. Considering conditions existing in many orchards, mechanical harvesting should reduce labor requirements by 75 percent and harvesting costs by 50 percent.

(4) Ventilation of livestock buildings--Research in cooperation with State Experiment Stations has obtained much needed basic data on the heat and moisture given off by cattle, hogs, and poultry, and on the influence of building environment on production and feed consumption. The heat and moisture dissipation data are considered basic design data for ventilation systems of poultry, dairy, and swine buildings. They appear in design handbooks including the 1962 Guide and Data Book of the American Society of Heating, Refrigeration, Ventilating, and Air Conditioning Engineers, and are used by makers of ventilating equipment, prefabricated buildings and package buildings as well as by specialists advising farmers on their

own construction. Building improvements resulting from the above research have contributed to the substantial rise in efficiency of livestock production that has occurred during the past decade.

(5) Research on light traps for insects, pioneered by AERD, has developed this device as a very effective means for detection and estimation of insect infestation. This development has aided quarantine activities and the planning of chemical control operations. More than 700 electric traps are in use to determine emergence and migration of the pink bollworm moth in the Southeast and the European chafer in the Northeast and thus facilitate more efficient use of chemical controls. An additional 400-500 traps are used for detecting mosquito populations. An estimated 400-500 general purpose electric traps are in use to determine new infestations of economic insect pests. Special multipurpose traps are used at points of entry to detect foreign insects.

The first field scale test of light traps for insect control is in operation in a 113 square mile area in North Carolina. Here 366 traps of special design are used for catching tobacco hornworm moths.

However, in spite of the rapid and unprecedented progress in farm mechanization during recent years, many important field and farmstead operations are still not mechanized or are only inadequately mechanized. There are also many unsolved problems in the mechanical preparation and conditioning of farm products for farm storage and use, and for sale. There are many undeveloped opportunities for the more effective and extensive application of the different forms of electromagnetic energy and there is urgent need for the development of more effective and economic farm buildings for storing products, sheltering livestock, and farm family living.

In view of the rapid multiplication and widening distribution of nuclear weapons and the failure of all current efforts toward disarmament, plans for future agricultural engineering research may well give consideration to types of building construction that would afford protection from fallout for families, livestock and stored products in case of attack. Consideration might also be given to development of types of essential equipment, such as well pumps, that could be kept in operation in case of power failure.

Agricultural Engineering research is carried out by the Agricultural Engineering Research Division of the Agricultural Research Service of the U. S. Department of Agriculture, by nearly all of the State Experiment Stations, and by farm equipment manufacturers, manufacturers of building materials and prefabricated buildings, and to a limited extent by trade associations. The relative scope of these groups is indicated by the number of professional man-years employed; i.e., 144 by USDA's Agricultural Engineering Research Division, 191 by the State Experiment Stations and an estimated 575 by industry and other organizations in 1961.

A characteristic of current Agricultural Engineering research is the relatively small program of the USDA and also of the State Experiment Stations compared to that of other "Units" of public research, to the agricultural engineering research by industry and to the volume of agricultural production. This imbalance is serious because 80 percent or more of all agricultural research involves engineering, either during its conduct or during the application of its positive findings. Also as agriculture becomes more complex the need for expanded public agency research in agricultural engineering to determine for industry the fundamental principles and the basic requirements of the power, machinery and structures needed for an efficient agriculture become increasingly urgent.

Thus, although there is need for the expansion of independent basic research in agricultural engineering, there is also need for a considerable expansion of agricultural engineering research cooperative and concurrent with other related agricultural research programs and also cooperative with industry whenever circumstances indicate the desirability of such cooperation. It should be noted that public agency research in agricultural engineering is complementary to and often cooperative with private research and not a competitive duplication of research by industry.

The Agricultural Engineering Research Division has 30 of its 144 professional workers located at the Beltsville Agricultural Research Center; 21 at 7 Federal field stations, and 93 at 33 State Experiment Stations.

Of the 93 Department professional workers now at State Station locations, 18 are in 6 specialized Federal laboratories, such as the National Tillage Machinery Laboratory at Auburn, Ala. Most are working cooperatively with State-employed workers on mutually agreed problems that have both State and National significance. Much of the research is carried on by teams including both engineers and scientists trained in other disciplines.

The program at Beltsville includes leadership for work done in the field and research on problems of National interest. Basic research involving 27 engineers conducted at 15 locations, including Beltsville, deals with soil and equipment relationships, pesticides and fertilizers application, crop conditioning, cotton ginning, environmental requirements (including light) for livestock, electromagnetic radiation for seed and plant product treatment, insect attraction and destruction, and nondestructive determination of fat and lean on live animals. Most of the work at other locations is directed toward solution of specific problems.

The program of the Agricultural Engineering Research Division is reported under 14 Research Areas shown in the Table of Contents. Brief statements on related 1961 programs of the State experiment stations and industry also are included.

AREA 1, SOIL - MACHINE RELATIONSHIPS

Problem. The substitution of the internal combustion engine for animal power has been the major influence on the farmer's productivity during the first half of the twentieth century. There have been important developments in the tractor chassis and its accessories, such as tricycle gear, power take-off, implement mounting, hydraulic controls, and pneumatic tires, but there is still a lack of fundamental knowledge and understanding of the method whereby tires and tracks transmit forces to the soil in developing traction. In view of the tremendous amount of power and energy which is used every year in farm field operations, all factors which may affect the efficiency of this use should be continually studied for potential improvements in efficiency.

There is need for basic information on how traction is developed by tires and tracks, and need for improved traction, and transport equipment. There is evidence that compaction of soils is becoming more common because of the increasing size of tractors and the more complete mechanization of field operations, particularly harvesting, which usually must be done at a given date regardless of the soil conditions; thus, associated with tire and track research is a need for study of methods of reducing soil compaction.

Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Some type of tillage operation is considered necessary prior to the growing of almost all crops. Despite this great need and cost, the tillage tools which are generally used have remained essentially unchanged since their invention, or most radical improvement, nearly 100 years ago, and very few innovations since have survived the tests of improved crops response and/or reduced cost of operation. While some tillage is needed for nearly all crops, there is good evidence that much unneeded and in some cases detrimental tillage operations are performed. The soil is a very complex physical system, containing inorganic and organic solids, liquids and gases, and its reactions to forces, manipulation, temperature, and water is unlike any other simple material. In view of the wide-spread use of, and great power consumption by, tillage, there is a need for expanded basic research to give more precise information on the inter-relationship of tillage, soil physical conditions, and plant growth; on the effect of soil mechanics upon the tillage operation; on the effect of equipment mechanics on the tillage operation; on mathematical methods which can be used to predict the effect of various forces on the soil; and on tillage methods and systems of equipment which are compatible with conservation farming practices. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic and crop conditions.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers and soil scientists engaged in both basic studies and the application of known principles to solve problems dealing with the relationships between soil-engaging equipment and soil reactions. The research findings are applicable to tillage implements, tractive and transport equipment (such as tires, wheels, and crawler tractor tracks), and soil moving equipment (such as land forming and road building equipment). Work is cooperative with the State Agricultural Experiment Stations at Auburn, Alabama; Ames, Iowa; Athens, Georgia; State College, Mississippi; and East Lansing, Michigan. USDA personnel working on this project are stationed at Auburn, Alabama, and Ames, Iowa. Much of the work of the laboratory at Auburn is with manufacturers of implements and equipment for use in agriculture. The research is of a fundamental nature of value to the entire industry and directly and indirectly to farmers. It consists of theoretical analyses, basic laboratory studies, controlled soil bin tests, and field observations.

The Federal scientific effort devoted to research in this area totals 7.3 professional man-years. Of this number 1.0 is devoted to traction and transport devices and soil reaction; 1.0 to the effect of tillage practices on plant growth; 1.2 to the measurement of soil physical properties; 1.5 to equipment mechanics; 0.5 to the effect of soil mechanics; 0.5 to methods of mathematical analysis; 1.0 to systems of equipment for conservation farming; and 0.6 for program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 13.0 professional man-years divided among subheadings as follows: 0.8 on traction and transport devices and soil reaction; 6.9 on the effect of tillage practices on plant growth; 0.6 on equipment mechanics; 0.7 on the effect of soil mechanics; 2.0 on methods of mathematical analysis; and 2.0 on instrument development for study of soil stresses. The current program is divided among the Regions as follows: North Central Region 6.1 professional man years; Northeastern 1.3; Southern 2.1; and Western 3.5.

Industry research in this area is chiefly by manufacturers of agricultural tractors and tillage equipment, and agricultural tractor tires. It is estimated that in 1961 Industry made an annual expenditure in this area of 70 professional man-years distributed as follows: 15 toward improving pneumatic agricultural tractor tires; 10 on improving crawler and other tractor devices; 15 on the effect of soil physical properties on plant growth; 15 on the effect of equipment mechanics; 5 on methods of mathematical analysis; and 10 on systems of equipment for conservation farming.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Traction and Transport Devices and Soil Reaction. This project is designed to determine and evaluate the effects of various construction, materials, and operational factors on the performance of tires and tracks when used for traction and for transport. Ten American made and two foreign made rear tractor tires were obtained through the efforts of the ASAE Tractive and Transport Efficiency Committee and tested. These tires differed in construction as follows: (1) regular profile-regular cord angle, (2) regular profile-radial cord angle plus belt (a tread ply of circumferential cords), (3) flatter profile-radial cord angle plus belt, (4) as for (3) but foreign made, (5) as for (2) except built to go on a 3-1/2-inch rim, and (6) as for (3) except built to go on a 3-1/2-inch rim. Each type was available also with the lugs ground off to simulate smooth tires.

The twelve tires were tested to study tread movement under two loads and at three inflation pressures. These tests show that tire design and operational differences produce characteristic differences in tread movement. These differences do not correlate with tractive performance and only partially with wear performance.

The twelve tires were tested in three soils and on concrete to measure the effects of the characteristics listed above on traction. Radial ply construction gives the largest improvement in pull. Radial ply and narrow rim construction improve power factor and other measures about equally and contribute more than flattened tread. Lug stiffness improves performance.

The foreign made tire was superior, especially in efficiency. It incorporates radial ply construction, a belt, flattened tread radius, and relatively stiff lug construction.

A rear tractor tire treated with a selected "parting compound" was tested to determine its effectiveness in shedding mud. The improvement noted was not sufficient to warrant recommending its use.

Effect of Tillage Practices on Plant Growth. Studies of basic factors applicable to the design of subsurface tillage implements were continued in 1960. Rooting of cotton was definitely deeper where the soil was well pulverized to a depth of 18" (by successively deeper passes of a sweep cultivator). The yield of cotton was 1.68 bales per acre on deep tilled (18") Lloyd clay loam as compared to 1.38 bales per acre on conventionally tilled plots (6" deep). There was no difference in the yield of cotton in 1960 between Lloyd clay loam tilled 12" deep with a vertical shaft rotary tiller and tilled 6" deep with conventional equipment.

In 1961 all plots of the 18" vs 6" depth of tillage experiment were treated the same to determine the carry-over effect of the deep tillage treatment. The yields of cotton were 1.67 bales/acre for deep tilled

(18") Lloyd clay loam as compared to 1.53 bales/acre for the check treatment (6"). In a deeper tillage experiment the rooting patterns were strikingly different and the yields statistically different. For the treatment of 36" depth of tillage and 36" fertilizer depth, the average length of taproots was 14.5" and yield 1.86 bales/acre; for 36" depth of tillage and 6" fertilizer depth the average taproot length was 13" and yield 1.71 bales/acre; and for the 6" depth of tillage and 6" fertilizer depth taproot length was 8.3" and yield 1.53 bales/acre.

The effect of cropping system and depth of seedbed preparation on peanut production was continued in 1961 for the third of 5-7 years. Results show that tillage and the amount of litter turned appeared to have little effect on the yield. This is contradictory to results of a similar experiment at another location. Yields following rye were significantly higher than for corn, cotton, or soybeans. Rye stubble was some better than where straw residue was incorporated.

Measurement of Soil Physical Properties. Evaluation of methods to determine tensile strength of soils was continued to include the influence of methods of molding on the ultimate strength and a comparison of simple tension and modulus rupture using Lloyd clay. Soil strength increased linearly with molded bulk density and increased with an increase of moisture content (but not exceeding the upper plastic limit) during molding. Tension and modulus of rupture measurements resulted in the same ultimate tensile strength. Measurements of draft, horsepower, and performance in turning soil were made for two high speed and a general purpose moldboard plows at 5, 7, and 9 inches plowing depth at speeds from 1 to 8 mph. The three plows performed about the same.

Equipment Mechanics. Results of tests made in 1961 to compare spherical, conical, and "Vertedor" disks in the Lakeland sand indicate that at a 35° disk angle the soil exerts a much greater downward force on the conical disk than on either of the other two. The "Vertedor" disk is a disk produced in Argentina which has a center section (approximately one half of the disk diameter) in which the curvature is reversed from that of the conventional disk shape. The "Vertedor" disk required about 20 to 25% more draft than the others. At a 45° disk angle, the regular (spherical) disk had a greater downward soil force than the others, while the "Vertedor" again required about 20% more draft. The action of the soil turned by the "Vertedor" disk indicates that it should do a better job of covering any material on the soil surface.

A comparison was made in sand and clay soils of forces on various moldboard landsides, shares, and colter equipment combinations. There was no big difference in the various landside arrangements. The disk jointer gave over 10% reduction in draft compared with the next closest colter arrangement. This reduced draft was accompanied by a reduction in the vertical force and an increase in side force. The principle of multiple cuts, such as demonstrated in these test by a disk jointer - moldboard

plow, offers possibilities of more efficient tillage.

Soil forces were determined on several commercially available 14-inch moldboard plow bottoms to evaluate their relative performance. Speed had more effect on the magnitude of soil forces than did differences between bottoms. Data show that there were differences in the bottoms; however, since the bottoms were tested in only three soil conditions at one depth, a clear superiority of one bottom over another was not established. In general, draft varied directly with the amount of lateral movement of soil.

Relative performance was determined for a conventional 14-inch moldboard plow, the Rotaspa plow from Holland (spades rotate about a horizontal axis that is perpendicular to direction of travel), and the Civello plow from Italy (curved blades rotate about a vertical shaft). In Decatur silty clay loam the Rotaspa plow gave a range of clod sizes from 0.7" mean weight diameter (MWD) at a forward speed of 0.25 mph to 3.25" at 1.3 mph. The Civello plow produced a MWD clod size of about 1" at forward speeds from 0.5 to 2.5 mph. The moldboard plow produced a clod size of approximately 2" at speeds from 2 to 6 mph. The efficiency of the Rotaspa and the moldboard plows was about the same when producing clods with a MWD of about 2". The efficiency of the Civello was less than one-half that of the Rotaspa when producing clods with a MWD of approximately 1".

Preliminary attempts to separate draft into the basic components of cutting, soil on metal friction and shear plus acceleration, showed the percentage of total force at 9 mph of cutting, friction, and shear plus acceleration to be 50, 8, and 42 for Lloyd clay; 42, 3, and 55 for Hiwassee sandy loam; and 35, 10, and 55 for Lakeland sand. Using similarity of soil reaction to vertical plane chisels from 3/4-inch to 4-1/2 inches wide in Lakeland sand, Hiwassee sandy loam, and Lloyd clay and formulated Pi terms, the data indicate that, with few exceptions, results of the models could be used to make acceptable predictions of the 4-1/2-inch prototype.

Validity of an equation by Zelenin for predicting resistance forces in cutting soil with plane metal surfaces was determined in three of the bin soils. Due to the exponent of depth decreasing with depth of cut, increasing with clay content, increasing with the angle of inclination of the cutting blade within the surface 8 cm., and the inability of the penetrometer to adequately describe soil strength, it was concluded that Zelenin's equation is not useful for general application.

In a laboratory experiment the influence of electro-osmosis (current flow across metal-soil inter-face) on the coefficient of sliding friction of metal on soil was determined for six bin soils and the coefficient of friction of Teflon plastic on the same soils was determined. Results of electro-osmosis ranged from negative at low moisture contents to a

maximum reduction of mechanical power of approximately 95% in moist Houston clay. Usually there were no reduction in total power requirements. Field tests of plastic covered moldboard plow bottoms showed that both Teflon and Polyethylene coverings did a good job of scouring the very sticky subsoil and covering debris. In 1960 tests, field life of the 0.135-inch thick high density Polyethylene was 15 acres and of the 0.2-inch thick Teflon was 50 acres. Field studies in 1961 confirmed that the volume wear resistance of Teflon is much greater than Polyethylene although laboratory studies indicated little difference.

Tests were made with various contents of spindle oil and ethylene glycol liquid binders in Houston clay to determine if it were feasible to use artificial soils to simulate natural field soils in laboratory tillage studies. Draft and velocity dimensionless parameters proved valid in predicting results of the 3.0 in. chisel from that of the 0.75 in. The correction factor $1/2n^2$ satisfied distortion inherent in the system. Since spindle oil has a low volatility rate and since a big loss in content affects strength properties very little, it is an excellent liquid binder for relative tests over a long period of time. Ethylene glycol imparted plastic properties to the soil and is a satisfactory fluid binder if necessary precautions are taken to keep down evaporation. It offers many possibilities of varying the soil parameters for both similitude and comparative tests.

Methods of Mathematical Analysis. Modifications have been made in the triaxial apparatus so that three dimensional stresses, three dimensional strain, and volume strain can be simultaneously measured and recorded on a volume element of soil. Satisfactory simultaneous measurements of stress and strain provide a means for determining stress-strain relationships for soil. A series of triaxial tests on four different soils was completed to determine the relationship between applied stresses (forces) and resulting volume strains (deformations) using soil screened through a 2 mm sieve and wetted to a uniform moisture content. The measurements at each applied stress state were replicated at least three times in Hiwassee sandy loam, Congaree silt loam, Lloyd and Houston clay soils. Because of the tedious nature of executing triaxial tests, two men required approximately three months to obtain 100 valid tests.

Invariants of the stress state, maximum normal stress, mean normal stress, maximum shearing stress, and octahedral shearing stress of soil, were compared with the resulting bulk density for the various manners of applying the stresses. None of the above invariants correlate with bulk density although the mean normal stress was much better than the others. Further analysis showed that a stress function composed of the mean normal stress plus the mean normal stress multiplied by shearing strain correlates with bulk density. Additional measurements on other soils and at different moisture contents will be required to fully verify

the relationship. To be useful, shearing strain will ultimately have to be related to applied stresses.

Systems of Equipment for Conservation Farming. Studies were continued on the effect of various seedbed preparation methods on initial stands, plant heights, silking dates, and grain yields on different soil types. Five seedbed preparation systems and two levels of fertility were used in these studies. Similar to previous results, soil moisture and climatic conditions seemed to have a greater effect than the seedbed preparation systems. Stand counts made prior to cultivation indicate that conventional, wheel-track, and ridge planting give better stands than mulch tillage or listing. These differences in stand are not always reflected in yields, and for the most part conventional tillage results in the highest yields, with wheel-track and ridge planting resulting in slightly lower yields.

Studies were continued on equipment and methods for preparing seedbeds and controlling weeds on ridge planted corn. (Ridge farming is similar to listing except that the crop is planted on top of the ridges rather than in the furrows, and on sloping land the ridges are laid out on the contour or with a slight grade. This system holds promise for preventing soil and water erosion, for reducing drowning in areas that need drainage, and for lowering labor and power requirements.) Corn planted on ridges tends to silk slightly earlier than with the other systems, and listing usually silks last. There was very little difference among the tillage systems for nitrogen and potassium uptake; however, listing tended to be lowest. Through the use of pre-emergence chemicals on contoured ridges that had been formed several years ago, it was possible to obtain almost complete control of runoff and erosion and to maintain a high level of stands and yields. Forming ridges with the plow (one-third of the land area was plowed) and shaping with disk-hillers results in stands and yields that are approximately the same as those obtained with conventional seedbed preparation. Complete rotations of corn-corn-oats-meadow have been grown on ridges in several fields.

Studies on the use of herbicides to eliminate seedbed preparation were continued. Early spring applications of atrazine, Simazine, and 2,4-D in the form of overall sprays were used on fall plowed, spring plowed, and unplowed cornstalk ground. Secondary tillage treatments of disking, strip tillage for only the corn row with a cultivator sweep, and tillage of an 8" strip for the corn row with a rototiller, were compared with no secondary tillage and with conventional plowing, disking, and harrowing. Results of these tests show that herbicide applications can be successfully substituted for seedbed preparation with tillage tools on fall plowed, spring plowed, and unplowed cornstalk ground. With atrazine and Simazine no mechanical cultivations were needed. However, mechanical cultivations were required when 2,4-D was used and also when no chemicals were used. On spring plowed land, none of the secondary

tillage operations significantly improved yields or stands. Although the stand and yield data were somewhat erratic, the results on fall plowed land indicate that tandem disking just before planting was superior to strip tillage or conventional single disking and harrowing. On unplowed land strip tillage was equal to disking and harrowing, and no tillage resulted in lower stands and yields. Cornstalks clogging the planter on untilled plots caused the poor stands that resulted in yield reductions. These results indicate that corn can successfully be grown in Central Iowa with little or no tillage if weeds are controlled chemically.

Studies were continued on methods and equipment for measuring soil shear to describe the physical environment for seedbeds. Measuring the energy input-to-failure of undisturbed soil sheared in torsion offers possibilities as a technique for describing seedbeds. Undecayed organic matter in the samples caused some difficulty, but results indicated that adequate results could be obtained by increasing the number of samples.

Studies were initiated on the development of a soil surface profile meter. This device will be used to describe the physical changes that occur on the soil surface as a result of tillage tool operations or plant growth. The device has been constructed and will be field tested in 1962.

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AREA 2, PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Problem. The history of the development of planting equipment now in use is characterized primarily by invention of machines which will plant seed in accordance with accepted practices. Introduction of chemical fertilizers was followed by specialized equipment for spreading this material. Early work on placing fertilizer close to the seed (starter fertilizer) was followed by the discovery that a certain position with respect to the seed resulted in the best response to starter fertilizer for particular crops.

However, there has been very little work on, and there is considerable present need for, precise seedbed requirements for various crops in different areas of the country. This seedbed requirement would include depth of cover, size of soil particles or clod surrounding the seed, degree of soil compaction necessary, and soil surface profile over the seed for best emergence. The planting geometry used on many crops is still the plant spacing which was necessary to permit horse cultivation. The exact best planting geometry for many crops is still unknown. The exact best placement for starter fertilizer is also unknown for a number of crops in different areas of the country. There is also a need for development and testing of fertilizer application equipment for unusual crop situations, such as hillside orchards, sugarcane, tree transplants, etc. While efforts in precision planting of crops in the past have not often resulted in discernible yield improvements, there is a renewed interest in precision planting of vegetables to improve uniformity of maturation to facilitate mechanical harvesting. As other needs for hand labor diminish and it becomes less available on farms, there will be an increasing need for completely automatic transplanting equipment which does not yet exist. There is an acute need for new and improved equipment and methods for effective planting of native range grasses in the arid areas of the Southwest which will result in a greater certainty of stand. Equipment is needed which can be used to re-seed relatively rough areas which are overgrown with undesirable species or have recently been cleared. There is also need for improved planting equipment and methods for forage crops in humid areas. Approximately a third of such plantings now result in poor stands and another third result in no stands at all.

USDA PROGRAM

The Department has a continuing long-term program involving engineers, of applied research on planting methods and means of applying fertilizer on various crops. Studies are underway at 30 locations in 14 states (Arizona, Delaware, Georgia, Indiana, Iowa, Louisiana, Maryland, Michigan, Missouri, Nevada, New Jersey, Texas, Washington, and Wisconsin). Sixty three field experiments were conducted in 1961 in cooperation

with the experiment stations of these states, other ARS divisions, and some commercial research units. This research involved studies with 34 crops and 24 special machines were provided to put in seed and fertilizer placement experiments this season - machines either solely or collectively designed and constructed by the Investigation Unit. Five new machines were designed and constructed by the research engineers, and alterations and refinements were made to several special machines used this year.

The Federal scientific effort devoted to research in this area totals 9.5 professional man-years. Of this number 0.2 is devoted to seed bed requirements; 1.1 to fertilizer placement and distribution equipment; 0.2 to seed planting equipment; 0.3 to transplanting equipment; 2.5 to equipment for establishment of forages; 2.1 to cotton planting and fertilizing equipment; 0.4 to vegetable planting equipment; 2.0 to decontamination of agricultural land; and 0.7 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 17.2 professional man-years divided among Regions as follows: North Central Region 4.6; Northeastern 0.6; Southern 10.3; and Western 1.7. By major subheadings for the states the man-years were as follows: seed bed requirements 2.4; fertilizer placement and distribution 4.6; seed planting 1.6; transplanting 2.3; forage and rangeland 0.9; cotton 3.4; and vegetable 0.8.

The current program of research by industry in this area was chiefly by the farm equipment manufacturers and the fertilizer manufacturers, a total of about 70 professional man-years. It is estimated that the research by the farm equipment manufacturers was distributed about as follows: seed bed equipment requirements 5; fertilizer placement and distribution 10; fertilizer corrosion 5; seed planting 25; transplanting equipment 5; and forage and rangeland planting equipment 10. Manufacturer's work in sugar beet planting equipment and cotton planting and fertilizing equipment is included under "seed planting equipment" above. It is estimated that fertilizer manufacturers are expending the equivalent of about 10 professional man-years for research and development in this area.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Fertilizer Placement & Distribution Equipment. Twenty-three field experiments were conducted at 14 locations in 1960. Vegetable and root crop tests were conducted in Arizona, Georgia, Michigan, New Jersey, Pennsylvania and Washington; small grains in Michigan and Texas, and row crops (corn and cotton) in Maryland, Nebraska, Nevada and Texas. The experiments conducted involved the use of 9 special machines designed for this purpose. The yields of winter wheat in Indiana in 1960

gave significant differences where fertilizer was placed in continuous bands 1" below the seed with 900# 5-20-20 fertilizer per acre when compared with the common method (contact w/seed, 31 - placement, 36 bu/A). Differences were also secured on the 600# and 300# rates, although they were not statistically significant.

In 1961, the establishment of field crops and vegetables were put in. Seventeen experiments were handled out of the Beltsville Station, three by the Southeastern Station and eight by the Southwestern Station. Some of the notable results in 1961 included response on: fertilizer placement on winter wheat, fertilizer application at time of planting tree seedlings, and application of high phosphate fertilizer at time of planting tomato seed. In cooperation with Michigan State University, a field experiment with the Investigation's special drill for research on winter wheat showed an increase over conventional drilling in 7" rows in contact with fertilizer of 15% greater yield (37.5 to 43.3 bu/A) by placing the fertilizer in a continuous band to the side and below the seed row (about 1" X 1"), or a 19+% greater yield (37.5 to 44.8 bu/A) by drilling in 4" rows (instead of 7" rows); or the combination of the above two practices gave a crop yield increase of 37% (37.5 to 51.3 bu/A - fertilizer contact with seed in 7" drill rows vs. fertilizer side placed to 4" drill rows).

Fertilizer placement studies were made on corn in 1960 and 1961. In conventional planting, the initial fertilizer containing 1/3 of the nitrogen is applied at planting time 2" to one side and 2" below the seed, and the remaining 2/3 of the nitrogen applied as a side dressing 8" to the side of the row, 2 to 3" deep. Results of two years' studies have shown that higher yields can be obtained by using either of the following treatments: (1) same initial placement as conventional but with the side dressing placed 8" deep in the middle, or (2) all fertilizer applied at the time of planting placed 2" to the side and 2" below the seed.

Transplanting and Fertilizing Equipment. In cooperative tree planting on Maryland State Park lands with the W. R. Grace and Company (Fertilizer Research Division) the application of a specially designed fertilizer expressly for silviculture (magnesium ammonium phosphate, 8-40-0) at time of transplanting gave better wood growth in the first season on many species put out in replicated plots - Austrian pine, 15%; loblolly pine, 40%; tulip poplar, 67%; and black locust, 307%. In the past, adding fertilizer at time of transplanting of tree seedling has been considered an adverse practice in that the competitive plants usually first benefit from the added plant food. However, with the new fertilizer and techniques being developed, it appears the early stand and growth can be greatly increased.

Equipment for Establishment of Forages. In 1960 ten experiments on the establishment of pastures and haylands were conducted from the Beltsville station, twelve from the southeastern station, and ten from the southwestern station. As reported previously, many experiments showed earlier growth and more vigorous stands of forages with precision planting of seeds and placement of fertilizer at time of planting, in comparison with the common method of broadcasting seed and fertilizer. These differences were shown under conditions where the growing environment was poor - inadequate moisture and/or low fertility. In the Southeast, insects (army worms), weeds and extreme dry weather made several experiments unproductive. Precision planting and placement of fertilizer gave superior stands with birdsfoot trefoil in the Columbia, Tennessee area. Contact of phosphate fertilizer with this same variety in Georgia gave adverse results on establishment.

At Beltsville, a series of forage crop experiments were conducted on the growing of corn for green feed or silage. This is drilling corn with a grain drill at a rate of 3 1/2 bushels to the acre (some 300,000 plants per acre). No cultivation is required. This solid corn planting is harvested 6 to 8 weeks later when the corn is some 4' or 5' in height. Large tonnages were harvested (28T/A) but with a relatively high moisture content (85 to 90%). Nevertheless, two crops of this nature may be easily produced in this latitude which adds to the flexibility of a farm forage plan. With good practices, one should average almost double the dry matter normally produced by cultivated corn for silage. The principal disadvantages were greater seed cost, higher moisture content material to handle, and slightly less protein content of the roughage. On this heavy producing, short period growing crop, some small advantage was obtained from precision planting and placement practices, but with this first exploratory type experiment, it does not appear this type of culture will require new types of planting and fertilizing equipment.

In the Southwest, establishment of some ten varieties of forage had relatively poor results. Lack of adequate soil moisture in the seed zone seems to be the predominant establishment problem in the high plains area. Basic work on mulches, synthetic covers and other devices are being studied in the laboratory. At the present time, properly managed plastic films on the soils may effectively establish grasses, but the cost (materials and time) limits these methods to relatively small areas at the present time.

Two experiments on the use of liquid fertilizers were conducted in cooperation with the Georgia Experiment Station. No differences were found on crop production on millet and rye in comparison of solid, liquid and suspension type of fertilizers (second year). Response was significant on side placed fertilizer on millet in comparison with fertilizer in contact with the seed.

Nineteen experiments were conducted from the Beltsville Station in 1961, six from the Southeastern Station and four from the Southwestern Station. Outstanding finds this season include the use of nitrogen in the precision placement of fertilizer in the establishment of alfalfa. Cooperative studies in Piedmont soils in the Southeast showed significant increase in first yields of forage production with nitrogen in mixed fertilizer at time of establishment in comparison with the same treatment having no nitrogen in the banded fertilizer 1" below the seed. Also, after two seasons, in Georgia, forage production was increased over 1-1/4 ton per acre by the fall seeding of rye in bermuda sod in addition to some apparent increase in bermuda grass production.

In the Southwest, the record of four seasons on surface pitting and staggered listing on rangeland (for moisture conservation) shows the annual production of grass forage is being increased from 13% to 18% in comparison to the unaltered rangeland. Considerable amounts of weeds were present in the disturbed soil areas the first and some of the second season, but after this initial set-back in desirable forage plants, good range grass stands were established in the raw areas where the basins were formed. Blank listing in 20-foot strips on contour showed superior forage production to range pitters, except during the 1961 season.

Considerable progress was made in methods of establishing birdsfoot trefoil in grasslands in cooperative experiments with the Maryland Experiment Station. Special equipment to study methods by means of a single row treatment were designed and constructed. A single disc coulter gave excellent stands when used in conjunction with the common grassland drill shovel openers, which place fertilizer some 1 to 2 inches below the drilled seed in the grooved furrow. A specially designed winged opener also showed good performance. The new methods average 6 to 7 times more plants in the furrow than the conventional opener (6 week stand - Oct. 20). By March, all stands were reduced in number of plants, but 15 to 18 times more plants survived with the new methods. The results of this one season of work lead us to believe that birdsfoot trefoil which is ordinarily difficult to grow in grass stands, may be reintroduced in sod by these new methods.

Cotton Planting and Fertilizing Equipment. If crop residues do not decompose during the winter they often interfere with planting and other mechanized production practices. This problem is more common to the drier areas of the Cotton Belt but also occurs in the more humid areas where large cotton stubble and root crowns often fail to completely decompose. Two years ago the use of a special root and stalk disposal machine caused a slight delay in the maturity of the succeeding cotton crop in California probably because the nitrogen was not available during the early growth, but this effect was not significant this year. This machine used without any other primary tillage produced yields comparable to standard practices of seedbed preparation. Vertical mulching which placed three tons of cotton stalk trash per acre in a

subsoil trench two inches wide and 20 inches deep increased early growth and yields significantly over standard plowing but not over subsoiling alone at the same depth. A similar vertical mulching test with gin trash in Mississippi three years ago gave similar results of no response and there were no detectable residual effects on the plots in 1960.

More recently a new term, "precision tillage," coined to describe deep tillage in a position to be precisely under the row of plants, has attracted attention to project studies in California. Precision tillage gave an average yield increase of 37 percent in 1961. Tests indicate that the previous benefits of vertical mulching can be explained by the subsoiling rather than the mulch material.

Under the wet fall conditions during 1961, positive operating height adjustments for trailing-type horizontal-blade stalk cutters were attained by adding extra wheels to the conventional cutter. This allowed the outside wheels of the dual wheel arrangement to ride the shoulders of adjacent rows rather than follow the ruts left by cotton harvesters. By equipping the towing tractor with steel skeleton wheels, travel through rough, muddy fields was accomplished without the usual slippage of rubber-tired units.

Land grading is proving a greater asset to mechanized cotton production in the Mid-South Delta area than to the irrigated areas for which it was originally initiated. A 35-acre research field, graded for mechanization studies in 1960 permitted more efficient irrigation, more uniform stands, more timely operations, and more reliable plot results. Two 2 1/2 cubic yard scrapers were operated in tandem with a standard 55 horsepower tractor in correcting the topography of a typical Delta field to a side-slope of 0.05 and row-slope of 0.15 foot per hundred feet. The time per round was increased by less than 20 percent, by using the two scrapers behind a single power unit.

The Stoneville bed blade was as effective as conventional types of pulverizers in preparing seedbeds for planting in sandy loam soils. Best results were obtained by mounting the Stoneville underground applicator blade on a front-mounted cultivator frame immediately ahead of a V-shaped leveling blade. This arrangement provided a smooth, thoroughly pulverized seedbed for simultaneous planting with a rear-mounted planter. Preliminary test equipment was developed for planting directly behind the primary tillage operation. Equally satisfactory stands were obtained planting directly behind moldboard plowing, chiseling, rotary tilling, and middle-breaking on sandy loam soil. No surface refinement was provided; however, the early weed problem was minimized by the previous grading operations.

In another minimum tillage test in Mississippi, moldboard plowing followed by regular sweep cultivation gave highest yields of cotton, as compared with rototilling, chiseling, subsurface cultivating, and

middle-breaking in a Bosket fine sandy loam soil. The addition of chiseling four to six inches deep in the middles at time of each cultivation reduced yield in all primary tillage treatments. Stand was not affected by method of tillage in the 1960 trials.

An irradiation treatment on cottonseed of 150 milliamps, 60 cycles, 2 millimeters of mercury for one minute improved emergence of acid-delinted and gin-run seed, but had little effect on machine-delinted seed in Mississippi. Again, as in 1958 and 1959, there was a significant difference in rate of emergence among types of delinting for both treated and untreated seed.

"Hopper-box" seed treatment with a fungicide has become a rather common practice in some areas of the Cotton Belt. The addition of the fungicide to the seed in the planter hopper reduces the metering rates of the planter slightly. Laboratory tests were run in California to establish calibration values for this practice.

In a soil temperature, planting study, at two locations in Alabama there was no correlation of minimum soil temperature and cotton stand. Soil temperature guides developed in Texas do not seem to be applicable to Alabama climatic conditions.

The plateau, shallow furrow, deep furrow, and flat row profiles were again compared on sandy soils in the High Plains area of Texas. Plant emergence counts indicated slightly more rapid emergence in the shallower profiles at 10 days after planting. These results occurred with no precipitation and drying winds. There was no difference in final yields. This phase of the planting work in Texas will be terminated. A manuscript is in the process of publication.

Among seed press wheel weights from 0 to 100 pounds, the 17 and 35 pound weights per wheel gave best emergence, agreeing in general with last year's results at Lubbock, Texas.

At Lubbock the emergence obtained for each of several plastic mulch treatments was higher at the one percent level for 17 days after planting except for the first and 17 day. The mean soil temperature ranged two to three degrees higher under clear plastic than under black plastic and uncovered rows. Increased emergence and final yields were obtained by using either plastic cover during germination and emergence. The increased emergence was attributed to a measured trend of decreased physical impedance and increased air permeability and moisture in the seed zone.

A small disc opener was used to apply fertilizer in one trench of the plateau planter slightly below seed level at Lubbock. A rate of 40 lbs. N per acre applied in this manner was as good as higher rates applied in the same manner or later as a side dressing. In another test,

yield results showed that close placement of fertilizer for early use of plants is most important in this area.

Vegetable Planting and Fertilizing Equipment. Tomato seeds were planted in Georgia in 1959, 1960, and 1961, and given varied applications of fertilizer at the time of planting, (radioactive phosphate fertilizer was used the first two years, but that used in 1961 was not radioactive). The Georgia plants were transplanted in New Jersey and given uniform treatment until the maturity of the crop.

Two out of three years showed greater production of tomatoes when heavy phosphate fertilizer was placed below the seed. In 1959, 10 lbs. of P_2O_5 per acre gave a yield of 18 tons of tomatoes per acre compared to 130 lbs. of P_2O_5 which gave a yield of 25 tons of tomatoes; or a yield increase of 7 tons per acre for the heavier application. In 1960, 10 lbs. of P_2O_5 per acre gave a yield of 24 tons of tomatoes per acre compared to 70 lbs. of P_2O_5 which gave a yield of 29 tons; or a yield increase of 5 tons per acre for the heavier application. In 1961, all plots yielded around 31 tons per acre. Evidently the excellent growing conditions for maturing the crop in New Jersey overcame the effects of varying the initial phosphate applications to the seeds in Georgia in March.

Decontamination of Agricultural Land. A study is underway to determine how to remove radioactive fallout from agricultural lands in case of an emergency. Bare soil was treated with simulated fallout (small glass beads 18-40 micron diameter) and subsequently decontamination was attempted with a bulldozer, a road grader, a small and a large pan fill-type scraper and a laboratory designed vacuum sweeper. The large scraper was most effective in removing the fallout as it removed 99.8% of the activity. However, it also removed the topsoil to a depth of seven inches. The road grader removed 88% of the activity. The vacuum sweeper removed from 4 to 40%. Although performance of the first design tested was erratic, the maneuverability as well as the comparatively low amount of radioactive material to be disposed of make future developments of vacuum equipment attractive.

In 1961 tests were begun to test means of decontaminating pasture and hayland. Since rainfall affects the amount left on forage crops, tests were conducted with and without the crops exposed to a simulated rain applied with sprinklers. The first inch of simulated rain washed off about 10% of the fallout. Removing the vegetation using a flail forage harvester emptying into a canvas enclosed wagon resulted in removal of about 40% of the fallout. Removing the vegetation by means of a direct cut forage harvester resulted in only about 15% decontamination. While the flail removed more fallout it also scattered more around while it was operating, which was objectionable. A motorized vacuum street sweeper picked up about 35% of the fallout but was difficult to operate over rough land. A road grader removed as much fallout when operating on

standing hay crop as when operating on mowed hayland. A dense crop of soybeans was grown and removed after pasture land was partially decontaminated, in order to investigate the possibility of removing remaining contamination with the heavy vegetation. The effectiveness of decontamination by removing the crops depended on the thickness of the foliage, the amount of rain which washed the vegetation and the type of harvest machinery used.

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AREA 3, CROP PEST CONTROL TECHNIQUES AND EQUIPMENT *

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment, be it a small chemical sprayer or a giant bulldozer. In many situations, effectiveness of the equipment necessary may be essential to the success of the method which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control, and it is time consuming and costly. It is believed that with sprayers and dusters now used often no more than 10 - 20% of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provide sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the new Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa particularly for corn borer control; and at Wooster, Ohio, on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and

*Except electric, which is in Area 11.

cultural, is conducted at Ames, Iowa; St. Paul, Minnesota; Columbia, Missouri; and Stillwater, Oklahoma; and at Wooster, Ohio where a small part of an engineer's time on spraying equipment applies specifically to weed control. Aircraft application equipment is studied at Beltsville, Maryland in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington Stations, on low growing crops. Pest control equipment research for certain crops is conducted: for cotton at Auburn, Alabama; Stoneville, Mississippi; Shafter, California; and Lubbock, Texas; for peanuts at Holland, Virginia; and for vegetable crops at Forest Grove, Oregon.

The Federal scientific effort devoted to research in this area totals 13.8 professional man-years per year. Of this number 1.3 is devoted to basic studies in aerosols and spray formations; 0.7 to soil fumigation; 2.8 to insect control in grain; 1.6 to weed control in corn and soybeans; 3.6 to pest control in cotton; 0.2 to pest control in peanuts; 0.8 to insect and disease control by ground equipment in vegetables and other low-growing crops; 0.6 to aircraft equipment for application of pesticides to low-growing crops; 1.0 to aerial spray equipment for forest insect control; and 1.2 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State experiment stations in 1961 reported a total of 11.0 professional man-years, divided among Regions as follows: North Central 2.1, Northeastern 0.2, Southern 4.8, and Western 3.9. The largest single item for all of the Regions is 3.4 for weed control research. Pest control equipment especially for cotton, both in the South and the West, is another important single item, with 3.0 professional man-years. Work on spray formation devices and aircraft application is being studied, particularly in the West.

The research by industry in this field is conducted chiefly by manufacturers of: farm equipment, chemicals, and aircraft; with an estimated annual effort of 75 man-years. Estimated annual expenditures are equivalent to about: 10 professional man-years for soil fumigation, 25 for insect and disease control equipment, 15 for weed control equipment, 5 for spray formation devices, 5 for cotton pest control equipment, 5 for development of chemical formulations for improved distribution, and 10 by aircraft and aircraft equipment manufacturers.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Basic Studies in Aerosols and Spray Formation. The objective is to obtain basic theoretical and experimental information for use in improvement of efficiency and distribution characteristics of pesticide application. Theoretical work in aerosol mechanics dealt with introduction of a particle-size distribution into random motion theory. If mutual interference is neglected, it was found that the solution of the

random motion problem in probability terms, for particles of a single size may be simply multiplied by the particle-size frequency function. This work described the behavior of a group of various sized particles subjected to random molecular bombardment in a still medium, and studies are underway to extend these concepts to turbulent situations. The areas of statistical turbulence theory now involved in this work are statistical specification of turbulence, velocity and vorticity correlation and spectrum tensors, and the alterations necessary with the addition of suspended particles.

In work with fluorescent tracing of pesticide deposits, construction and adjustment of a densitometer was completed. Indexing of mercury arc spectrograms was done to provide a reference for determination of fluorescent tracer spectral lines.

The work on this subject has been chartered as the Pioneering Research Laboratory on Physics of Fine Particles.

Basic studies in Ohio included the effect which application of sprays of different drop size or pattern may have on control of insect pests or plant diseases. The 1961 experiments were on sugar beets for the control of Cercospora leaf spot. Tribasic copper sulfate was applied as a fungicide in flat and hollow cone spray patterns at 40 gallons per acre at ten day intervals beginning July 20 and ending September 7. Five treatments were applied by each spray pattern on each treatment date. These treatments varied from each other in mass median diameter by increments of 100 microns from about 100 microns to 500 microns. Rates of application were 40 and 160 gallons per acre. Disease infection became rather severe by the end of the season in untreated areas. As in similar experiments in 1960 when tomatoes were sprayed against diseases, control was good in all 1961 sprayed plots and there appeared to be no significant differences due to variations in drop sizes or type of spray pattern. Copper deposits and adhesion measured on foliage samples was high for all treatments. Five of the sprayed plots were sampled for sugar content and all showed an increase of at least 800 pounds per acre over the unsprayed treatment. Differences in sugar content do not favor any drop size or spray pattern.

Soil Fumigation. Various formulations of fungicides, nematocides, insecticides, and herbicides, were applied to soil. Special equipment was developed and adapted for distributing liquid, granular and volatile materials to the soil. Crops grown included ornamentals, vegetables, fruit, and forest nursery stock. The field cultivator with large coil spring shanks and back-swept knives was successfully used to apply liquid materials. "Plant safe" material was again applied to single rows at each side of the plant root zone with good success. Heptachlor was applied to soil by a rotary tiller at 6 and

200 lbs. per acre rates to study residue of heptachlor epoxy in root crops. No effect on growth of red table beets, radishes, carrots, turnips, potatoes, or onions was found at the 6-lb. rate. Some residue was found in carrots; but none was found in any other of these crops at that application rate. When applied at 200 lbs. per acre, this material reduced the yield of beets, potatoes, and onions about one half and residue of heptachlor epoxy was found in all the above crops.

Equipment was developed for applying liquid insecticide or fungicide directly in the row when planting onions or other vegetables. It was used very successfully, particularly for investigating the control of onion maggot and onion smut. Equipment was also prepared for application of side dressing treatments at seeding time. The effectiveness of a number of volatile pesticides can be increased by sealing the soil surface for about 48 hours after application. Experimental applications of liquid materials such as asphalt or wax emulsions and even water were effective enough to warrant continuation of this line of investigation. Such materials may be less expensive and more conveniently applied than the polyethylene type of film now in use.

Insect Control in Grain. Work was done on the development and evaluation of equipment for control of the corn borer in Iowa. Corn borer infestation in 1960 was extremely low, and the insecticide and application equipment investigations were curtailed. Emphasis was placed on new materials that would be effective without leaving objectionable residues on corn stalks and ensilage and on studies of distribution of granules with application equipment. Results of residue studies indicate that EPN can be applied three times at rates of .55 lb. per acre if a 15-day waiting period prior to harvest of sweet corn is used without exceeding the allowable 1.0 p.p.m. in the canning factory waste. The granular formulations resulted in lower residues than equivalent amounts applied in sprays. Equipment was developed and a method devised to measure the amount of granular material intercepted by the corn plant during applications of granular insecticides for corn borer control. Results of tests indicate that corn plants at 30-inch natural height intercept less than 30 percent of the total granules applied. Corn borer control equipment field experiments in Ohio were not completed during 1960 because of the low borer infestations in Ohio where tests were planned.

In Iowa during 1961 the development and evaluation of equipment for control of corn borer and screening tests of both liquid and granular formulations of new insecticides, were continued. One of the more promising new chemicals for controlling corn borer larvae in field corn in 1961 was Telodrin applied at 0.2 lb. per acre. The liquid and granular chemicals tested caused little or no problems with application equipment. Studies on the evaluation of insecticide applications for borer control on corn yields show that greatest yield reductions occurred when insecticide applications were delayed.

Studies were continued to determine the most effective granular size for borer control. In 1961 the 40/50 mesh sizes were most effective for second brood borer control. Previous work has shown very little difference within the 15/60 mesh size ranges for first brood control. Granular mesh sizes below 60 were difficult to meter and distribute. Differences in borer control between the larger and smaller mesh sizes were insignificant. These results indicate little or no practical value for the design and development of equipment for applying fine mesh granules.

Field experiments on corn borer control with ground machines at Wooster, Ohio, were abandoned during 1961 because borer infestations were too low to conduct tests. The corn borer hydraulic spray equipment was used in corn earworm field experiments on sweet corn. The earworm populations were heavy, often several worms were in one ear. Six spray applications were made within a fourteen day period starting with 1 percent of the ear shoots showing silk and ending after 100 percent silking. Two wide angle, hollow cone nozzles per row, one on each side, gave good coverage of the silk zone when applying 35 gallons per acre at 40 psi. The most effective insecticide was Sevin which gave 96% clean ears. A combination of DDT and malathion gave 93% and DDT alone 85% clean ears.

Weed Control in Corn and Soybeans. Studies were made in Iowa in 1960 and 1961 on the early application of herbicides to corn to eliminate the need for soil manipulation for seedbed preparation, and if possible through the growing season. Atrazine, Simazine, and 2,4-D sprays were applied in early April on fall-plowed, spring-plowed, and unplowed cornstalk ground. Various degrees of secondary tillage ranging from none to several diskings and harrowings were performed on the sprayed plots. Atrazine and Simazine gave full season weed control, and 2,4-D up to planting time. Results indicate that it is possible to grow corn profitably without any seedbed preparation if the weeds are controlled chemically. The previous crop residue on the ground caused some planting problems.

In Missouri in 1960, a pre-emergence treatment of 20 lbs. per acre of Na PCP plus cultivations as needed was the best combination of mechanical and chemical weed control and gave the highest soybean yield over a four-year period. Results based on corn yield indicate no significant difference between liquid and granular 2,4-D when applied at 1-1/2 lb./A. However, when applied at 3 lb./A the liquid formulation caused damage to the corn while the granular treatment did not affect the corn yield.

Studies were conducted in Iowa in 1961 to evaluate practices and types of cultivating equipment for controlling weeds in corn fields. Harrowing after planting did not materially improve weed control, but caused a slight reduction in stand, and reduced yields where sweep cultivations

only were used. Three sweep cultivations were superior to two in terms of yields, stands, and weed control. The differences between two and three sweep cultivations were not significant when used in combination with shallow cultivations performed with rotary hoes, weeders, and dragging hoes. The results of this and previous studies indicate that the cost of weed control on corn can be reduced by using combinations of shallow and sweep type cultivators.

Studies of the effect of three tillage methods on three weed control methods were conducted in 1961 at one location in Missouri. Corn stands and yields were significantly lower and weed yields significantly higher on strip-tilled plots than in plots prepared by either the plow-plant or conventional methods. Corn yields were significantly higher and weed yields lowest in plots receiving atrazine as a pre-emergence weed control treatment. These results indicate that a full season chemical weed control treatment is essential during seasons when weather conditions prohibit adequate mechanical cultivation and that the roughness of the soil surface due to tillage methods had no effect on the activity of the herbicide treatments.

Field studies were conducted in Missouri in 1961 on the effect of shields, row spacings and other combinations of mechanical and chemical weed control practices. Shielding soybean plants while spraying the weeds with 1-1/2 lbs/A of 2,4-D amine was no better than the same treatment without shields. Studies were made to determine the effect of row spacing on Clark soybean yields with and without pre-emergence treatments of amiben at a rate of 3 lbs/A. With 24-, 32-, and 40-inch row spacings, the amiben was less effective in controlling weeds than was two cultivations without amiben. With 8- and 16-inch row spacings amiben was quite effective in controlling weeds without cultivation.

Studies were made (in Missouri) in 1961 to determine the effect of directed post-emergence applications of dalapon and 2,4-D on corn. Treatments of dalapon at 4 lbs/A and a mixture of 2,4-D (1/2 lb/A) and dalapon (4 lbs/A) were applied to corn with exposure to the corn stalk from 0 to 5 inches. Leaf lifters were designed to raise the corn leaves while the stalk and weeds were sprayed. Results indicate no reduction in corn yield when 5 inches of stalk was sprayed with dalapon at 4 lbs/A. This treatment has possibilities where heavy infestations of grass make it necessary to use a nonselective herbicide such as dalapon.

Studies were continued in Iowa in 1961 to evaluate various granular herbicide formulations and to develop methods and equipment for accurate and efficient application. Pre-emergence studies on corn and soybeans continued to show that granules were as effective as liquids. Studies were made to determine the number of granules required per unit area of soil surface for effective weed control. Using 2,4-D

ester granules of various sizes showed that 0.3 granules per square inch were as effective as 5.2 granules per square inch when measured in terms of number of surviving weeds in mid-June.

Studies of the metering characteristics of granular herbicides were continued in 1961 with tests of some of the common granular applicators. Results indicate that the fine granules tend to move to the bottom and the coarse ones to the top of the hopper as the applicator is operated. With most of the commercial applicators, the amount of material discharged from the applicator did not vary directly with the speed of the agitator so that relatively constant field speeds are required for accurate metering. An error of about 10% in discharge rate due to inaccuracy of the metering device was common with the granular applicators used. An experimental screw type metering device was tested and found to vary in feed rate directly with the screw speed. However, the discharge was pulsating rather than a desirable steady flow.

A nozzle test stand was developed in 1960 so that spray nozzles could be accurately calibrated. Results from calibration studies show that a 10% difference in discharge rate between nozzles of the same size from the same manufacturer is not uncommon.

Basic studies of rotary hoe performance were continued at Minnesota. (The rotary hoe is used for cultivation and weed control.) Values of vertical and horizontal operating forces on rotary hoe teeth were computed using certain assumed relationships between displacement and forces and found to agree well with measured values of these forces obtained from strain gage dynamometers. Operating forces required to maintain a constant operating speed and depth of penetration were found to vary considerably with the design of the tooth. There is no consistent relationship between the magnitude of vertical and horizontal operating forces and the operating characteristics of rotary hoes having different tooth configurations as measured by the quantity of soil disturbed. The quantity of soil disturbed was found to be an indicator of the effectiveness of the rotary hoe for cultivation and weed control and was found to be greatly influenced by tooth configuration.

Pest Control Equipment for Cotton. In California, an experimental rotary cultivator design was found to be superior in efficiency for soil incorporated herbicides to designs reported previously. The power requirement was found to be considerably less than other designs also. Soil incorporation of post-emergence herbicides was found to be more efficient in controlling weeds than surface application under furrow irrigation practices. Several soil mixing devices restricted emergence of the cotton in both herbicide and fungicide applications.

In Mississippi, controlling the depth of placement of an experimental herbicide with an underground applicator showed that deep placement (three - inch) increased herbicide activity; but to date, no combination

of depth and rate has produced both a satisfactory combination of cotton tolerance and weed control. Latest developments include a subsurface applicator for dust and granular materials and refinements in the liquid applicator nozzle arrangement. Mixing the herbicide with the soil again showed no advantage over concentrated subsurface layer or horizontal band deposits.

In a study of weed control combinations in Alabama, use of a pre-emergence chemical, a post-emergence oil, flame cultivation, and sweep cultivation held the hoe labor requirements to less than three man-hours per acre without affecting yield or picking efficiency. In another test, a lay-by chemical applied 20 days before normal lay-by time saved two sweep cultivations and did not affect picker efficiency, cotton quality, or yield. At Lubbock, Texas, a pre-emergence chemical gave the highest saving in hoe labor, but the weed infestation was too light to make the saving economical. None of the weed control programs completely eliminated hoeing.

In comparing the effect of parallel and cross flaming on weed control and crop tolerance, less damage occurred with the parallel setting in 4-inch cotton; however, it appeared doubtful that enough weed control was accomplished to justify this method of operation. Both parallel and cross flaming were more effective when combined with a herbicide treatment than either method alone. Although early flaming damaged young cotton plants, yield was not significantly affected in this Mississippi test. Conventional burners and lay-by spray applicator nozzles both performed satisfactorily when operated in combination with regular sweeps on a rear-mounted cultivator. The primary advantages of this system include (1) reduction in cost of cultivating equipment, and (2) simultaneous operation of two weed control tools. Field tests on a more recent experimental method of mounting and gauging flame burners resulted in control of the flame at least as accurate as when the burners were mounted on conventional skids.

A parallel-action wheel-type chemical applicator that can be used either as an attachment to a front-mounted cultivator or a rear-mounted tool-bar was designed and tested. This applicator gave better weed control than a conventional skid or shoe in applying a post-emergence oil and was also used satisfactorily in applying lay-by herbicides.

Granular herbicide distribution was improved in Alabama by using a chain drag ahead of the granular discharge to roughen the surface and reduce lateral movement of the granules. Weed control was good on clay soil but poor on sandy soil.

Fifteen applications of insecticides were applied in comparing a hydraulic boom-type sprayer, an air sprayer, and a mist blower. However, insect populations were not high enough to show differences in

control. The application of defoliant with the air carrier sprayers continued to show a great deal of promise.

In California the mixing of fungicide dust with the cotton seed was found to be inefficient for disease control and to lower the efficiency of seeding. In Mississippi a high-clearance, self-propelled machine was modified to carry a four-row plot sprayer and duster for boll rot control in a cooperative study with pathologists. Evaluation tests with fluorescent dust showed a 90° elbow turned to the rear approximately 12 inches above the ground gave satisfactory plant coverage. In Alabama several fungicides were sprayed on heavily irrigated cotton to prevent boll rot. Natural plant defoliation occurred early and no benefits from the fungicides could be detected.

Pest Control Equipment for Peanuts. In Virginia stem rot control practices involving ridge planting and non-dirting cultivation were compared with results from ridge and furrow planting with dirting cultivation. Only the ridge planted treatments received a herbicide. In an area of light stem rot infestation ridge planted and non-dirting cultivation had 0.5 percent of the plants infected with stem rot, 187,000 weeds per acre requiring 46 man-hours of hoeing labor, and yielded 1,873 pounds of peanuts per acre; ridge planted and dirting cultivation had 2.4 percent stem rot infected plants, 43,000 weeds per acre requiring 23 man-hours of hoeing labor and yielded 2,330 pounds per acre; furrow planted and dirting cultivation had three percent stem rot infected plants, 41,000 weeds per acre requiring 25 man-hours of hoeing labor and yielded 2,359 pounds per acre. In an area considered to be infected with stem rot the above practices showed: Ridge planted, non-dirting had 0.6 percent infected plants, and yielded 2,030 pounds per acre; ridge planted, dirting cultivation had 3.8 percent infection, and yielded 2,536 pounds per acre; furrow planting and dirting cultivation had nine percent plant infection, and yielded 2,788 per acre. These results showed dirting treatments had higher stem rot infection but higher peanut yields in locations when stem rot incidence was low. Weed and grass control without covering or damaging the peanut vines is a major problem in peanut production.

Studies continued on cultural practices incorporating combinations of herbicide applications and mechanical control resulted in variations on effectiveness of weed control and hoeing requirements. During an unusually high rainfall period, hand hoeing requirements ranged from 11 man-hours per acre when treated with a post-emergence application of herbicide (Dinitro) and cultivated close to rows to 46 man-hours per acre when treated with a pre-emergence application of herbicide (Dinitro) and not cultivated close to rows. In this rainy season six pounds of Dinitro applied per acre as a post-emergent reduced weed infestation by about one-half when compared with nine pounds of Dinitro applied as a pre-emergent. Two applications of Dinitro, with the

second application applied in granular form have for the second consecutive year been so effective in weed control that no hand hoeing was required. Highest yields came from those treatments having the least weed infestation.

Insect and Disease Control by Ground Equipment in Vegetables and Other Low-Growing Crops. Studies with air-blast sprayers were carried on in 1960 in the control of Cercospora leaf-spot on sugar beets in northwestern Ohio. All of the experimental plots were sprayed with a turn-table type air-blast sprayer. The standard application used was 40 gallons per acre rate over a 40-foot swath with treatments made at 10-day intervals, beginning about August 1 and ending about September 12, a total of five applications. In addition to this basic outline, deviations in individual experiments involved variations in pump pressure, gallonage per acre, number of applications, and in the width of the sprayer swath. Six copper-containing fungicides were compared on the basis of their ability to control leaf-spot. All six copper fungicides gave effective disease control with three of them, Copper A, COC-S, and Cy-Q-Plex showing the best control. In a comparison of six organic fungicides, maneb was most effective with Dyrene ranking second.

In 1961 experiments were continued with hydraulic and air-blast sprayers for control of Cercospora leaf-spot on sugar beets in northwestern Ohio. Hydraulic spray application at 40, 60, 80 and 160 gallons per acre showed no significant difference in disease control but at 20 and 30 gallon per acre the disease control was less effective. A new type of sprayer designated by the name "Spray-Foil" was used to apply 10 and 15 gallon rates and resulted in disease control approximately equal to the hydraulic spray applications. However, certain mechanical features of this machine made it difficult to operate and maintain. Air-blast sprayer applications of maneb with a turn-table type machine gave excellent disease control with no significant difference at 20, 40 and 80 gallons per acre rates. The spray distribution over a 50-foot swath was slightly irregular but was adequate for effective disease control at all application rates used. Increase in yield over unsprayed check plots with 40 gallons spray rate was 4.5 tons of beets and 2,106 pounds of sugar per acre. This increase in beets and sugar was higher than any other spray method or formulation used.

The air-blast sprayer has various advantages and some disadvantages when compared with the older type of fixed-boom, hydraulic sprayer. One of the factors that promoted its initial development and its present tendency to replace its fixed boom predecessor has been the fact that it operates with a high degree of efficiency in the distribution of the "concentrate" or low-gallonage sprays. A comparison was made in which maneb fungicide was formulated and applied at different quantities of water per acre. The 20 gallons per acre rate gave the best control of leaf-spot with the 40-gallon rate a close second. In

a comparison of spray pressures at 300, 150, and 75 p.s.i. no significant difference was shown in disease control. A common fault in use of air-blast sprayers is for the operator to over-extend the capacity of a specific sprayer to spray a wider swath than it is capable. A comparison of various swath widths, showed that 30 feet was less than the effective width, that 50 and 60 feet was too wide, and 40 feet the optimum width for the particular machine. The use of oil added to copper fungicides increased the leaf-spot control over the copper fungicide alone, but it apparently decreased the yield of beets and sugar. In a series of timing experiments the most effective spray schedule tried was started on July 21 and followed at ten-day intervals until a total of six sprays were made. A series of experiments with an air-blast sprayer for control of disease on canning tomatoes at wide ranges in plant populations was conducted until a hail storm destroyed the test plots and the experiment was not completed.

Comparisons of hydraulic sprayer with hooded boom and an experimental air-blast sprayer were made in grape vineyards in northern Ohio. The hooded boom sprayer gave a higher deposit of spray material on the fruit than the air-blast machine as determined by chemical analysis.

Tests were conducted, using a test rack developed for the purpose, to study the effect of nozzle arrangement on uniformity of coverage of selected areas in low-growing crops. In one series of tests a cylinder-shaped collecting device was propelled through the curtain of spray from nozzles arranged at various positions. In another series live potted strawberry plants were used with spray collector tabs attached to both sides of leaves at selected areas. An effective nozzle arrangement for coverage in this test was two nozzles on each side with one nozzle angled forward 45 degrees and the other angled to the rear 45 degrees. The use of supplemental air blast at the nozzles improved the spray distribution. An air-blast sprayer equipped with special volutes for treating low growing crops, was tested to determine the amount of coverage obtained on top and bottom leaf surfaces at various distances from the machine. This machine was designed for applications to both sides at the same time. Rows were spaced 42 inches. Applications were made with the nozzles and adjustments as made by the manufacturer. Rather variable spray deposits were obtained particularly at the outer areas of the swath. The first six rows from the machine received spray deposit on all top and bottom sampling areas. The spray coverage with air-blast sprayers depends upon proper nozzle arrangement and adjustment.

Spray applications were made to rows of bush beans in Oregon on which selected leaves were tagged on both the top and underleaf surfaces. Two nozzle arrangements were used, one with three overhead and two under-canopy nozzles per row, and the other with two overhead and two under-canopy. Both arrangements showed measurable amounts of spray on 91.1 percent of the sampling areas with the highest percent of measurable spray on the upper surfaces. A spray deposit test was made with an

air-blast sprayer in a field of bush beans. Sampling tags placed on tops and underleaf surfaces of plants in each row indicate that relatively good coverage was obtained.

Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-Growing Crops. In Oregon an experimental distributor for granular material was developed and mounted on a Rawdon agricultural airplane for test purposes. It is essentially a stream-lined housing resembling a small wing through which material is conveyed and released, however, it is not designed to produce lift. Deposit pattern tests were conducted in which granular material was released from a three feet and six feet outboard position. A maximum effective swath of 30 feet was obtained. Other pattern test data indicated that wider swaths may be obtained by releasing a portion of the material farther outboard. A swath width of from 40 to 45 feet can be obtained with a flight elevation of 5 to 8 feet if a portion of the material is released 9 feet or more outboard the airplane centerline.

A series of applications were made in Oregon to test insecticidal effectiveness and methods of application on control of the two-spot mite on pole beans. Three materials generally recommended, namely Dibrom, diazinon, and Trithion showed the best immediate control. A considerable variation in insect control from row to row was obtained with outside rows showing better control than rows closer to the line of flight, due to overlapping effect of two adjacent swath applications.

An aerial spray penetration test was made in Oregon on a field of commercially grown potatoes. Results of tests showed 77.8 per cent of all sampling areas received measurable amounts of spray. On the tops of leaves at the upper level 82 per cent of sampling area received measurable amounts of spray for which the mean rate was 2.68 gallons per acre. On the bottoms of the same leaves 73 per cent of the areas received spray with mean deposit rate of 1.8 g.p.a. On the tops of leaves at the lower level 81 per cent received spray with mean deposit rate of 1.76 g.p.a. The bottoms of the same leaves at the lower level 75 percent of sampling areas received spray with mean deposit rate of .89 g.p.a.

Spray distribution pattern studies conducted in 1961 with Piper PA25 and Rawdon T-1 low wing monoplanes and a Cessna 182 high wing monoplane showed that a symmetrical nozzle arrangement is more satisfactory than a non-symmetrical arrangement. The crossover of spray from the right side to the left in the center zone of the swath is not as pronounced as for aircraft like the Stearman and N3N which use larger engines and propellers. The most desirable spray swath pattern with a Cessna 182 was produced when the spray boom was mounted diagonally from the bottom of the fuselage to near the wing tip with the outboard nozzle 30 inches below the wing.

Applications of aldrin and heptachlor were made during October to red clover fields for control of the clover root curculio which gave effective control.

A series of experiments for control of Cercospora leaf-spot on sugar beets was conducted in Ohio. A Piper Cub J-3 airplane was used to apply 10 gallons of spray per acre over a 30 foot swath. The most effective fungicidal formulation used (maneb, tribasic copper and oil-in-water) gave disease control of 71 percent. This resulted in an increase in yield over the untreated check of 3.4 tons of beets and 800 pounds of sugar per acre. However, it was less effective in disease control than hydraulic and air-blast types of ground machines.

Experiments in aerial application of granular insecticides for corn borer control on early sweet corn were conducted in Ohio. The airplane used was a Piper J-3 equipped with a hopper, ram-air type distributor, and metering device for dispensing granules and other dry materials. Applications were made at 20 feet altitude, 75 miles per hour, 30 pound rate per acre and 35 feet swath width. The borer control in ears using two applications of 5 percent granules of DDT, Sevin and Dylox were 81, 90 and 94 percent respectively. Collections made of granules across the swath showed a very irregular distribution pattern. Improvement is needed in this type granular applicator.

Field tests were conducted in Oklahoma to compare the drift from an invert water-in-oil emulsion with the standard oil-in-water emulsion when applied aerially with a helicopter. Based on the number of droplets in oil sensitive dye-cards, the extent of drift with the invert emulsion when applied with a spinning disk applicator was as much as the straight oil-in-water emulsion applied with a conventional boom. There are more droplets produced by the oil-in-water emulsion than with the invert emulsions. Results indicate that some fine droplets are still produced with the invert emulsion which tend to drift as much as the straight oil-in-water emulsions.

Aerial Spray Equipment for Forest Insect Control. Studies were conducted on the development of aerial spray equipment and operational procedures for more effective control of forest insects. Degree of spray atomization is an important factor in control of forest insects by aerial spraying. A series of flights were made with a Piper PA18A to determine the atomization produced by various sizes of hollow cone TeeJet nozzles commonly used by airplane spray equipment manufacturers and commercial spray operators. Five different sizes of nozzles were used. Each size nozzle was used at each of three orientations--rear, down, and forward and down 45° to the thrust line of the plane. Atomizations obtained ranged from 130 microns estimated mmd (mass median diameter) for the smallest nozzle when directed forward and down 45°, to 298 microns for the largest nozzle when the orifice was directed to the rear 180° to the thrust line. There was a 60 to 65 percent increase in mmd when

nozzles were turned from a direction forward and down 45° to the thrust line to a rearward direction. Doubling the output increased mmd by only 7 to 15 percent and quadrupling the output increased it only 15 to 25 percent. These tests showed that orifice direction was a much more import factor than size of orifice.

The TBM is one of the large aircraft most commonly used for forest insect control. A series of 13 flights were made with a TBM to determine the average effective swath width for this plane. The flights were made at 50 to 100 ft. altitude and 170 mph airspeed. These tests show that with a spray of medium atomization the TBM is more effective at a swath of 300 ft. than at 400 ft., the width commonly used on earlier control operations. Our recommendation for the narrower swath was followed on one control operation in 1960 and results were very satisfactory.

For some time there has been a need for a quantitative spray assessment method with greater accuracy than the red-dyed card method of estimation but considerably less complicated than the dye tracer method. It was decided to develop standards for the use of black dyed spray on white cards for quantitative estimates by visual comparison, as has been done with fuel oil on red-dyed cards. An optical colimeter was used to measure the quantity of spray on aluminum plates placed alongside white Kromekote cards at sampling stations across the swath. Representative cards were selected with deposits from 0.1 g.p.a. by tenths, and by 0.25 from 1 g.p.a. to g.p.a. These cards with known deposits are the standards with which cards having unknown deposits can be compared.

Test flights were made with the TBM in 1961 to determine the width of swath at different deposit levels by means of black-dyed spray on white cards, using the flow rate required for a 300-foot swath at 1 g.p.a. A medium atomization of about 160 microns mass median diameter was used and height of flight was 100 to 150 feet. It was found than an average of 72 percent of the spray released from the aircraft was recovered on the ground. This percentage is considerably higher than had been obtained in the past and shows an improvement in technique. These tests of swath width confirm the decision to use a 300-foot rather than a 400-foot swath for spraying with TBM planes on forest insect control projects.

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AREA 4, CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, only recently initiated, has already resulted in sizeable cost reductions, but the potential savings for these crops and vegetables are enormous. Tobacco requiring over 400 man-hours per acre currently, also has long needed mechanization.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is currently restricted to a survey of citrus research needs and feasibility. Equipment for cotton harvesting is under study at State College and Stoneville, Miss.; Auburn, Ala.; Lubbock, Texas; and Shafter, Calif.; in cooperation with USDA Cotton Ginning Laboratories and the respective Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Mich.; Wenatchee, Wash.; and Davis, Calif.; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots, plums, grapes, blueberries, cherries, and dates. Development of new techniques for harvesting forage is underway at Beltsville, Md., and at Tifton, Ga., in cooperation with the Georgia Experiment Station. Research on forage seed harvesting is underway at Corvallis, Ore., and Clemson, S. C., in cooperation with the State Experiment Stations, farmers, and industry. Grain harvesting research is underway at Ames, Iowa, and Experiment, Ga., in cooperation with the State Experiment Stations. Long fiber crops harvesting research at Belle Glade, Fla., is cooperative with the

Everglades State Branch Experiment Station. Research on oilseeds and peanut harvesting equipment and methods is cooperative with the Experiment Stations at Stillwater, Okla., (castor beans); Bogalusa, La., (tung nut); and Holland, Va., (peanuts). Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minn. Equipment and methods for harvesting sugarcane are under study at Houma, La., in cooperation with the American Sugar Cane League.

A contract with the University of Sao Paulo, Brazil, provides for investigations in mechanization of sugarcane production. Its duration is for five years and involves P. L. 480 funds with approximately \$49,000 equivalent in Brazilian cruzeiros. Tobacco harvesting research is conducted cooperatively with the Experiment Stations at Lexington, Ky.

The Federal engineering effort devoted to research in this area totals 28.4 professional man-years. Of this number 0.4 is devoted to citrus; 4.8 to cotton; 7.1 to deciduous fruit; 1.5 to forage; 2.2 to forage seed; 1.6 to grain; 1.7 to long fiber crops; 3.6 to oilseeds and peanuts; 2.0 to potatoes; 1.0 to sugarcane; 2.0 to tobacco and 0.5 to program leadership.

RELATED PROGRAM OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 48.8 professional man-years divided among subheadings as follows: Citrus 2.4; cotton 7.6; deciduous fruit 6.7; forage 8.0; forage seed 3.7; grains (except rice) 2.4; oilseeds and peanuts 1.2; potatoes 2.2; sweet potatoes 1.1; rice 2.5; sugarcane 2.5; sugar beets 0.2; tobacco 2.0; and vegetables 6.3. Citrus and cotton harvesting research is being conducted in the Southern and Western Regions. Grain and oilseeds and peanut harvesting studies are underway in the Southern, Western, and North Central Regions. Research on potato harvesting is carried on in the Northeastern, North Central, and Eastern Regions. Harvesting research for deciduous fruit, forage, forage seed, and vegetables is conducted in all four regions. Sugar beet harvesting is under study in the North Central and Western Regions. Rice and sugarcane research is carried on in the Southern Region. Tobacco harvesting is studied in the North Central, Northeastern, and Southern Regions. Sweet potato research is carried on in the Northeastern and Southern Regions.

Industry and other organizations conduct engineering research on equipment and methods for the harvesting of crops. Both full line and small manufacturers cooperate in USDA research through loan of equipment. Farm operators and organizations furnish land, equipment,

and facilities for evaluation of experimental harvesting equipment. Much of the industrial experimental development of harvesting equipment is highly confidential and is generally not made available to public researchers. Estimated annual expenditures are equivalent to approximately 175 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Citrus Fruit Harvesting Equipment. In response to a request by Congress, a study was made of the feasibility of special engineering research on mechanical aids in the harvesting of citrus crops. To carry on this study, an engineer was detailed to Florida for four months during the 1961-62 harvesting season. Another engineer spent approximately one month studying citrus production in the California area. Visits were also made to Arizona and Texas to study problems in those areas. The report of the study, as submitted to Congress, included an analysis of the current state of citrus mechanization, results of preliminary USDA research, and a suggested future USDA research program.

During this preliminary study period, several tree and limb shaking devices were made available for testing by the USDA at the Citrus Experiment Station, Lake Alfred, Fla. While time did not permit investigation of the performance and efficiency of machines with wide ranges of amplitudes and frequencies, fruit removal of 50 to 70 percent was achieved using strokes of 1- to 1 1/2-inches. It is probable that the proper combination of frequency and strokes will remove over 90 percent of the fruit. The USDA engineer also assisted Experiment Station workers in a study of the use of an oscillating air blast as a fruit removal method. Using oscillating blasts with velocities up to 125 m.p.h., 99 percent separation of grapefruit was achieved in the tests. Considerable leaf damage resulted, however. The effect of damage to the tree and to the fruit with either this method or by the shaking method while currently unknown, will be determined in future trials.

Cotton Harvesting Equipment. Mechanizing the cotton harvest is an extensive and involved process with each of the cotton producing states engaged in one or more phases of the problem. While most phases of the overall cotton production mechanization research are reported separately, a sharp delineation between all phases is impractical since each field operation must be measured for its effect on succeeding operations.

Bottom defoliation of relatively short plants with dense foliage had no effect on picker performance but decreased yield as much as 600 pounds of seed cotton this year in Alabama. In California no differences in picking efficiency, seed cotton trash, and fiber quality

measurements were found between defoliated and desiccated cotton plots. Bottom and slot (between the rows) applications of defoliants on cotton at the time the first boll opens decreased the incidence of boll rot but also decreased yield.

A small air-delivery sprayer was evaluated and modified for applying defoliants in cotton in Mississippi. Minimum air-delivery volute heights of 26, 39, and 56 inches all gave good defoliation of mature leaves, but the high setting gave best results on second growth. It was found that a short boom was needed below the air stream to cover lodged cotton under the path of the blower volute. Tests also showed that rotation of the blower was necessary to allow for changes in wind direction and speed.

Cotton topping. Removing the top six inches of cotton plants in mid-August and pruning branch terminals four times during peak fruiting did not affect yield or foreign matter content but picking efficiency was slightly reduced by topping. Lodging was not a problem in the test area this year in Mississippi. A 10-year topping experiment was concluded in California. Briefly, conclusions are that topping reduces lodging without reducing yield when not more than about six inches of plant is removed. Topping to a height of about 48 inches gave the best results.

Skip-row planted cotton. Four rows in and four rows out did not affect picker performance and increased yield 15 percent per area planted over solid planting in Alabama. For both inside and outside rows, the row receiving irrigation water from only one side yielded as much as the row which received water on both sides.

Varietal characteristics affecting cotton pickers performance. In variety harvesting tests in Alabama there were no large differences in picker performance among 25 varieties. In a variety-spacing-irrigation test, two levels of irrigation did not differ materially in their effect on machine performance or plant characteristics. There were definite and important differences in harvesting efficiency due to spacing and variety and there was an interaction of spacing and variety. For all varieties, harvesting efficiency increased as plant population increased but the increase varied with variety and amount to 8.4 percent for DPL Smooth Leaf, 5.6 percent for Auburn 56, and 3.0 percent for Empire. There were large differences in harvesting efficiency among varieties for the thin spacings but not the thick spacings. For all varieties, harvested yield remained nearly constant at two bales per acre as plant population increased from 20,000 to 80,000 plants per acre but declined slightly at thinner and thicker populations.

Moisture in seed cotton from spindle-type pickers. The moisture increase of seed cotton caused by water transfer from the spindles of a cotton harvester to the seed cotton was determined for various conditions in a tapered broached spindle picker in California for the second year. From 30 to 50 percent of the water used by the machine is deposited on the seed cotton. This agrees with last year's results, but for unknown reasons the values were not affected by relative humidity, speed, nor wetting agent like they were last year.

Factors affecting cotton storages. In a broad study in Mississippi involving defoliation, seed cotton moisture and storage, relative humidity and temperature, the temperatures existing within a stored bale of seed cotton were higher when the cotton was harvested from undefoliated plants than when the cotton was harvested from defoliated plants. High seed cotton moisture was beneficial to staple length if ginned immediately, but was detrimental to lint grade and staple length when the seed cotton was stored prior to ginning.

A continuation of studies on environmental effects on lint and seed quality tended to confirm 1960 results in Mississippi. Again, lint and seed quality were affected by the length of exposure of the open bolls in the field. A more basic study consisting of storing seed cotton in environments of known relative humidities and temperatures indicated that seed cotton can be safely stored in humid areas if the temperature is kept lower than 50° F. It was also evident that a degree rise in temperature is more critical in relation to seed cotton deterioration than a percent rise in relative humidity.

Bottom picking cotton with machines. Modifications and adjustments were made on three different mechanical pickers for picking bottom-defoliated cotton in Mississippi. About two percent less trash was obtained with top eight rows of spindles shielded than with regular picking on the International one-row, high-drum machine. However, further streamlining will be required on the spindle shields to prevent pulling off green bolls. Removing the top eight rows of spindles and inserting plugs caused little damage to the plant, but left some cotton unpicked. The Rust high-drum picker did little damage to green bolls with three upper crowder channels removed.

Sources of trash in cotton harvesting. A study was begun to determine if any presently-available types of cleaners might be suitable for mounting in the air duct of a picker. Trash and moisture tests were made on an experimental cleaner and drier mounted on a Rust picker. Although the drier was found to be ineffective in removing moisture, the cleaner removed about half of the total trash in the cotton. It was more effective in removing large trash than small.

Oil contamination measurements on lint cotton. A quick and simple method of determining oil content on lint cotton was developed to aid in future studies of oil contamination. Tests on lint samples taken from mechanically harvested cotton showed that the picker contaminated the cotton with from 0.02 to 0.45 percent oil by weight of lint. Cotton harvested immediately after the picker was serviced contained more oil than cotton harvested toward the end of the day. Servicing followed the manufacturer's standard recommendations. Small-scale laboratory tests indicated that an addition of only 0.29 percent oil to lint cotton caused a slight increase in picker and card waste and nep count while slightly reducing yarn strength, break factor, and appearance index.

Spinning performance of machine-picked cotton. Harvesting tests were run in Mississippi in 1960 and 1961 and in California in 1961 with three types of harvester spindles and hand-picking. Spindles used were 9/16-inch tapered-broach, 1/2-inch straight barbed, and 3/16-inch straight smooth spindle. The primary purpose of this test is to determine the influence of spindle picking on spinning performance of cotton. Preliminary spinning results on only the 1961 test are available to date. In the California cotton there was no difference in the average number of ends down between hand-picking and machine-picking nor among any of the types of picking spindles. Differences were greater in Mississippi but the results have not yet been analyzed for significance.

Anhydrous spindle moistening agents were again employed in large-scale picking and spinning tests in an effort to find one with no harmful effects on cotton quality and with an ultimate objective of finding a material that would prevent deterioration of cotton in storage. Hexadecyl alcohol, when used at a rate of 0.35 gallon per bale, had no adverse effect on fiber properties or spinning. However, when 0.82 gallon per bale was used, a considerable increase in nep count and ends down resulted. Using the low alcohol rate plus a fungicide as a moistening agent resulted in a slight reduction of ends down while spinning the treated cotton.

Since bleach 2BS significantly improved spinning performance of lint in 1960, this study was expanded to determine the most desirable rate of bleach to apply to seed cotton while harvesting. Bleach was applied at three rates which covered the maximum practical range of application. No particular rate had a harmful effect on fiber properties or lint color. All three lots of bleach-treated cotton spun slightly better than the check.

Cotton picker head modifications and improvements. Tests were conducted to determine the effect of experimental contoured compressor sheets, low boll pickup attachments, contoured compressor sheet ribs, automatic header control device, cotton saver shields and

Ret-Bar pressure plates on picking efficiency and machine performance. There were no differences in picking efficiencies between the contoured and standard compressor shields. While the contoured sheets allowed the cotton to remain close to the spindles for a longer period, the only result was a slight increase in plant damage. The automatic header control for a two-row picker worked well, allowing the operator more time to check other parts of the picker. The cotton saver shields were effective in guiding low-hanging limbs into the picker, especially on the outside rows of skip-row cotton; however, some difficulty was encountered in traveling over uneven ground. No improvement in picking efficiency was obtained with the Ret-Bar pressure plates in early-season trials.

Recovery of cotton picker losses. A notched-belt seed cotton gleaner performed well in initial trials in the Delta area. The principle and operational features of the machine are good, but it does not appear to be practical for use after first picking. The gleaner picked up most of the leaves that had fallen after defoliation and seed cotton trash contents reached as high as 70 percent. The amount of cotton recovered in late-season tests ranged from 100 to 600 pounds per acre and contained about 30 percent trash. The average turnout was about 27 percent and the lint was worth from 29 to 30 cents per pound. The use of this machine after stalks have been cut is possible but presents a more serious ginning problem.

Stripper-type cotton harvesters. The experimental stripper elevator for immature boll separation was redesigned and further evaluated. The limited plenum chamber used last year was eliminated in favor of a three-volute fan scroll. This gave more uniform air distribution in the air conveyance-separation section of the elevator. With an immature boll content of only one percent in the harvested cotton, this machine was 80 percent efficient when the moisture content of the immature bolls was at least 70 percent. It was observed that harvest date has a more pronounced influence on quality preservation than the separation of immature bolls. Because of this, the machine possibly has more value as a green boll separator during earlier harvest, than as an immature boll separator for quality and value improvement.

Differential harvesting. Harvesting the top one-third and the bottom two-thirds of the crop separately was repeated on a small plot, hand-harvest basis to determine the value of this method of harvest for segregating the immature portion of the crop. Results show that as much as 80 percent of the immature cotton will be harvested in the top one-third of the plant when the crop is 90 percent mature, but only 30 percent of the immature bolls will be harvested

in the top third when the crop is 40 percent mature. This interaction, coupled with the high amount of mature cotton located in the top third of the plant, tends to limit the practicability of differential harvesting as a method of separating the mature and immature portions of the crop.

Field moisture content of mature stormproof cotton. This study was outlined to determine the moisture content-relative humidity relationship of stripped cotton components for relative humidity below 20 percent. Although these low relative humidities did not occur this year, equations expressing a high degree of reliability for estimating moisture content from ambient relative humidity in the 20 to 85 percent range were established for bur cotton, seed cotton, burs, lint, and seed.

In a broad harvesting-storage study incorporating defoliation, seed cotton moisture, and storage variables, lint and seed quality data were collected in an effort to determine the optimum picking and storage conditions necessary for minimum quality deterioration. Highest quality seed was realized when the seed cotton was harvested at a low moisture content from defoliated cotton in Mississippi. Free fatty acid content of seed was higher in undefoliated cotton than in defoliated cotton. Storing seed cotton from undefoliated cotton for three days reduced the seed viability. Picker efficiency was slightly higher and seed cotton trash content slightly lower for defoliated cotton. Best lint color resulted from harvesting when seed cotton moisture content was low. Defoliation reduced fiber upper half mean length, mean length, and strength.

Microbial activity in stored seed cotton was effectively reduced by applying a fungicide to the cotton. Fungicides, bleaches, and moistening agents were used alone and in combination as spindle moistening agents in an attempt to preserve cotton quality and improve picker performance. Three treatments--(1) bleach, (2) moistening agent alone, and (3) fungicide and moistening agent--all spun significantly better than the check (water).

Deciduous Fruit Harvesting Equipment. Harvesting is the only step in the growing, handling, and packing of apples that has not been extensively mechanized. It is a major problem because of high costs, periodical shortages of labor, and difficulty of harvesting the entire crop at proper maturity. Growers in all apple-producing areas need techniques and methods which will make harvesting easier and less costly. A unique fork lift attachment for the tractor-mounted picking and pruning boom was designed and constructed. The attachment makes it possible for the worker to empty his picking bag into a bulk box or container without getting out of the "cage." Time studies showed a worker increased his picking rate on fresh market apples by 24.7 percent. The hedging machine was used for

pruning the same thirty acres of cherry, peach, and apple trees as in FY 1960 and for pruning the four-year-old tree wall plantings of apples. Results showed that pruning costs were again materially reduced, that a satisfactory job of pruning was obtained and yields were the same as hand-pruned trees. Two types of inertia shakers (hydraulic and pneumatic) and a boom shaker were used to harvest 20 Hubbardson apple trees and 10 Bartlett pear trees. The fruit was collected on self-propelled low-profile frames. Design criteria for both shakers and frames were obtained.

The self-positioning conveyor tube and bin filler elements of the "pick and drop" equipment were redesigned and mounted on a "Steel Squirrel." Time studies on orchard trials with this equipment showed an increased picker output on fresh-market apples of approximately 22 percent as compared to regular picking with a ladder. Preliminary equipment consisting of an adjustable height hopper and an elevator was designed, constructed, and tested in picking hedge row plantings. A 19 percent increase in picking output compared with regular picking methods was obtained.

Bulk box handling of tree fruits. The bulk box handling methods developed under this project have become standard practice in all major deciduous fruit producing areas of the United States and Canada. During the 1960 season, over 50 million bushels of apples, pears, peaches, and prunes were handled in bulk boxes with a resultant saving to the industry of over two million dollars. The water flotation dumper developed last year was used successfully in emptying over 400,000 bushels of apples. Twelve other units patterned after this one have been constructed and used. This project is being discontinued.

Cultivated blueberries are grown commercially in the Mid-Atlantic States, the Great Lakes area, and the Pacific Northwest. Although equipment and methods which greatly reduce the cost of harvesting and packing blueberries have been developed, costs are still rather high and can be reduced further. Follow-up studies of the mechanical picking unit developed on this project showed that over 25 percent of Michigan blueberry crop and about 10 percent of the New Jersey crop was harvested mechanically at less than half the cost of hand-picking. The experimental continuous blueberry harvester was completely redesigned and reconstructed so that spindles will rotate through the canes without injuring them and at the same time vibrate for berry removal. The unit was not field tested during 1961. A semiautomatic cellophane packing unit was designed, constructed, and tested. Results showed it increased a worker's rate

of packing by 12.7 percent. The continuous blueberry harvester will be given extensive trials to determine fruit recovery, rate of travel, r.p.m. of spindles, amplitudes, and frequency of rotation, etc. An attachment for the packing unit which will automatically place the pint box in position has been designed and constructed and will be tested in a commercial operation.

From one-third to one-half of the gross returns of both sweet and sour cherries are paid to the workers who harvest the crop by hand. These workers are becoming increasingly hard to recruit--a situation which exists in all cherry-producing areas. The purpose of the research is to reduce the harvest costs and labor requirements through mechanization. An inertia shaker was designed and constructed and tested for harvesting cherries. Results showed that this type shaker recovers a higher percentage of the fruit, transmits more shake to the tree, and is more maneuverable than boom type shakers. A set of self-propelled low-profile frames was designed, constructed, and tested. Preliminary tests showed that decelerator strips are necessary over conveyors and desirable over deflecting surfaces, that slopes should be kept to a minimum if excessive bruising is to be prevented. Data again showed labor savings of over \$50 per hour and a variation of quality grades from excellent (over 95) to poor (under 80) depending upon the operation and equipment used. Instrumentation and apparatus were developed for evaluating cushioning materials and for studying velocities and bruising of falling fruit. This equipment consists of a 23-foot tube, lamps and photocells for measuring velocities, strain gages for measuring impact forces, two amplifiers, and recording equipment.

Extensive trials with chemicals for loosening sweet cherries showed that the chemicals tested were unsatisfactory. However, results indicate that sweet cherries allowed to reach full maturity increase in size and weight by 31 percent, that they can be harvested by shaking, and that it may be possible to brine them. The possibility of harvesting cherries for brining outlets at full maturity will be investigated in more detail.

About 225,000 tons of Concord grapes are produced each year in the six states of New York, Michigan, Washington, Pennsylvania, Arkansas, and Ohio. Conventional harvesting and handling methods are expensive and cause considerable damage to the raw product. Seven types of bulk boxes for handling grapes were designed and constructed:

(1) nailed wood, (2) plywood, (3) black iron, (4) stainless steel, (5) galvanized iron, (6) black iron painted with enamel, and (7) black iron coated with plastic. All boxes contain a hinged door for emptying. A dumper was also designed for emptying the boxes. However, due to the very short grape crop during 1961 in Michigan, commercial bulk box handling trials were not made. An automatic box-pick-up unit was designed, constructed, and mounted on a tractor.

This unit picks up boxes and elevates them to a trailer which is pulled behind the tractor. Preliminary trials of the unit are very encouraging. The box-pick-up unit will be field tested and if it shows real promise, it will be used in a commercial operation and time and cost data obtained.

The possibility of harvesting prunes mechanically in the California Coastal (Santa Clara Valley) growing area was studied. In this area the prunes fall to the ground when abscission of the stem forms at maturity. This presents a risk for a catching frame operation, as a high percentage of windfalls could occur which would have to be picked up by hand. The studies, therefore, were conducted to determine the feasibility of using catching frames and mechanical shakers (like those used in the Sacramento Valley) as a method of harvest. Three different methods of shaking were used--(1) trunk-circular, (2) trunk-linear, and (3) limb-linear--in the two different orchards. The tests indicated that mechanical shaking can be selective in the Coastal areas by shaking lightly the first time through. A large difference in the amount of windfalls between the two orchards was evidenced (10 percent of the total crop in one case and 22 percent in the other). This shows the degree of risk that would be involved in using catching frames. Depending on yearly conditions, any one grower might be successful one year and not the next. Based on the experiences and conditions of this year's tests, it seems that in order to assure a successful harvest every year, a pick-up operation or a blower-catch operation to cover a large acreage quickly is essential. In the Sacramento Valley an estimated 25 to 30 percent of the prunes were harvested mechanically and handled in bulk containers. Horsepower requirements for shaking were determined and results are being analyzed. An orbital trunk shaker was designed, constructed, and tested. Results showed the trunk-type shaker removed five percent less fruit than limb shakers.

Clingstone peaches and apricots. Hand labor for harvesting tender flesh fruits has become difficult to recruit. The possibility of selective harvesting with shakers and the effect of fruit injury were studied. On apricots a degree of selectivity was attained using an inertia shaker, with the best results at frequencies of 250 to 400 c.p.m. and about 1 3/4-inch stroke. On Clingstone peaches selective harvest by mechanical shakers is possible to a degree but it is felt not to be satisfactory for commercial operation. Results indicated that the best procedures for mechanical harvesting of cling peaches are (1) one-through harvest (all trees and fruit harvested), (2) two-time through harvest where only mature trees are harvested. Studies also showed that it is essential that decelerator strips and proper padding be used on catching frames if a minimum of fruit injury is to be expected. This padding must be of sufficient thickness to remove the energy from the fruit without causing excessive stresses. For average conditions, 3/4-inch sponge rubber, 1/2-inch ethafoam, and 1 3/4-inch foam plastic seem to be effective.

Mechanical thinning of peaches. Red Haven peaches were thinned with a boom type tree shaker at two orchards. Counts were made of the number of peaches on branches in different parts of the tree before thinning, immediately after thinning, and approximately one week later. At harvest the number, size, and weight of the fruit was obtained. Bark damage was studied. All data was taken on hand-thinned, machine-thinned, and a combination of hand- and machine-thinned trees. Results showed the thinning was random--no difference between tops and bottoms, that satisfactory thinning was obtained and mechanical thinning saves about 50 cents per tree.

Past attempts at mechanization of date harvesting have been concerned mostly with developing picking aids rather than mechanical removal of fruit. Time studies showed that 60 percent of the time of a worker was spent in actual hand-picking. Maturity studies indicated that it was possible to harvest bunches instead of individual ripe dates. Studies also showed dates could be handled in bulk boxes 18 inches deep instead of small lugs. Two types of equipment were designed and developed for separating dates from bunches which have been removed from the tree. Both vertical shaking and stripping tines look promising.

Forage Harvesting Equipment. Field curing studies on Coastal bermudagrass indicate a rotary mower will give a faster drying rate than a sickle bar mower and crusher. When the side of the rotary mower, against which the material would first be thrown after cutting, is removed, the amount of finely chopped material is reduced. This reduced harvesting losses but also appeared to reduce the drying rate to some extent. The use of a flail harvester has not been satisfactory to date because of the excess amount of sand which it incorporates in the material.

Previous studies with alfalfa have shown that the use of hay conditioners and proper management have decreased the field hay curing time as much as 50 percent. These studies were concerned with the 7-foot cut which is standard for most mowing machines. Manufacturers have recently introduced self-propelled windrowers or swathers which are designed to handle 10- to 14-foot swaths. Because this type of equipment offers a great reduction in man-hours in harvesting hay since it combines the mowing and windrowing operations, studies were undertaken to determine its operational effect on the drying rate. Two trials were conducted on second-cut alfalfa comparing a 12-foot windrower equipped with conditioner and the now conventional system of mowing and conditioning a 7-foot swath followed by raking after a period of drying. The results of both trials were similar. None of the methods resulted in hay of sufficient dryness for baling on the first day. The conventional 7-foot swath system did have the fastest drying rate, however. During the second day of exposure, the drying rates for the different systems, with one exception, were

approximately the same, thus allowing the hay to be baled by the middle of that afternoon. Hay prepared by the self-propelled swather without the conditioning attachment was definitely not dry enough for baling the second day, thus requiring another day's exposure to weather hazards. The results of these trials thus demonstrate the feasibility of using a self-propelled swather with conditioning attachment as part of a hay-harvesting system.

Forage Seed Harvesting Equipment. Research was conducted on harvesting equipment to determine the efficiency of the cutting and feeding mechanisms in gathering crops for the purpose of improving the equipment and methods in order to reduce the seed shatter and damage losses.

At Clemson, South Carolina, a study was made to compare standard cutterbar sickle sections with tungsten carbide cutting edges. The tungsten carbide edges were found to stay sharp longer and to be more durable than the standard sections. Research studies designed to measure the energy requirements with an accelerometer and Brush recording attachment for various knife angles at several velocities failed, as any test apparatus which was rugged enough to withstand the rapid accelerations was not sensitive enough for the tests.

A study was also made at Clemson to compare the cutter bar shatter loss in harvesting crimson clover using a "wind-reel" with the shatter loss sustained when using a tined pickup reel. Test results showed no significant difference in seed loss with the two reels. The seed loss was unusually low for crimson clover, averaging around 20 percent in all tests.

Improved seed harvesting techniques. In an effort to reduce the excessive seed loss and damage in lotus harvesting, research at Corvallis, Oregon, was continued, comparing conventional windrowing to windrowing on paper, on clear plastic, and on black plastic. Retrieving windrow shattered seed on the sheets increased the percentage of seed saved from 19 percent to 75 percent. Thermometer and thermocouple checks of the temperatures of the ground and of the sheets indicated a high of 150° Fahrenheit on the black plastic. Tests showed no significant difference in germination between seed windrowed on the ground and on the sheets.

In three years' tests in crimson clover on combine cylinder speed and clearance studies, a setting of 5/32-inch cylinder concave clearance and a 4,200 foot per minute peripheral speed of the cylinder gave the highest yield of pure live seed for the spike-tooth cylinder; whereas, a 5/32-inch clearance and a 5,000 foot per minute speed was peak for the rubber-covered bar cylinder. In all tests the rubber-covered bars and concaves gave a higher seed yield than the spike-tooth cylinder. Cleaning shoe settings of 5/8-inch gave the best results.

In Merion and Newport bluegrass harvesting survey to determine the seed loss and damage for the two-year average, the farmer was found to be saving 64 percent of the seed that he produced as pure live seed. The largest single loss was field germination loss which averaged 18.3 percent. Other losses were windrow germination loss--1 percent; shatter loss--6.6 percent; and combine loss--11 percent. Two-year results in harvesting orchardgrass revealed that the farmer was saving 55.8 percent, with the largest single loss being a 24.2 percent shatter. Germination losses were 11.6 percent; combine loss 4.6 percent.

Optimum moisture content for seed harvesting. At Corvallis, Oregon, a battery-operated moisture meter was used in connection with harvesting crimson clover, ryegrass, bluegrass, and orchardgrass. The samples were then oven-dried and the data correlated and plotted so that the seed moisture could be quickly and accurately determined as a guide to the time to cut seed crops for maximum recovery of seed. The time of harvest tests were repeated for lotus. Test results indicate that the optimum time to cut and windrow lotus is when 12 percent of the seed have shattered.

Corn Harvesting Equipment. At Experiment, Georgia, the results of two years of trials show that for the Southeast, if corn is harvested at a moisture content of 20 to 22 percent, highest efficiencies will be obtained and losses will be lower. This confirms results obtained previously in other corn areas. While preliminary studies also indicate a minimum of kernel damage by the harvester at this same moisture range, the extent of damage is more dependent on machine adjustment.

At Clemson, South Carolina, the simple low-cost corn header attachment for a combine developed in 1960 was refined and field tested on both pull-type and self-propelled type combines. The higher capacity of the self-propelled machine resulted in higher ground speeds and lower cleaning losses. Operating at 5.8 miles per hour, the unit performed well in 100-bushel-per-acre fields of corn. The ear corn loss averaged 3.5 percent. The unit was also tested in sweet sorghum, grain sorghum, and soybeans.

Long Fiber Crops Harvesting Equipment. Work on ramie harvesting and defibering machinery has been closely tied in with a similar project on kenaf since the basic harvester-ribboner has been adapted to each fiber by the range of adjustments provided for stalk height, forward speed, width of cut, and other fundamental characteristics. The field harvester-ribboner has been completely rebuilt to incorporate improvements needed that could not readily be incorporated in the old machine. The major details of the new machine are listed under the kenaf project.

The experimental plots at Belle Glade and at the Palm Beach County Farm for developing harvesting and farm handling equipment for bamboo have not matured as rapidly as expected thus preventing initiation of field test work. Growth on the peat soils continues to be much better than on the mineral or sandy soils. Laboratory studies have been confined to tests on cutting. A shear type harvesting blade similar to a large middle breaker appears more suitable for large scale harvesting than any of the saws under test.

The sansevieria harvesting program has had two lines of approach; namely, developing a harvester-decorticator and renovating and stimulating growth of the leaves on some of the slow growing plots. The rotary cutter seems superior in every way to the reciprocating sickle. High knife velocity can be maintained without vibration. High knife velocity is necessary in order to cut the dense, almost solid mass of leaves at the ground. A gathering and elevating mechanism has been developed which consists of modified number 55 hook chains and a 3/4-inch pitch roller chains working together to deliver a steady blanket of leaves to the decorticator. The regrowth after harvest has also been noted, especially the cold resistance of the young leaves. The best regrowths were secured from an area that was plowed under then disked and cross disked and limed. The next best regrowth resulted from plots where cut leaves had been allowed to fall and form a mulch over the rhizome beds. This will be the equivalent of spreading the waste back on the field as harvest progresses. Short stubble and clean ground gave the poorest results.

Work on the development of improved harvesting machinery for kenaf and similar fibers during the past season has been devoted to rebuilding the field harvester-ribboner. Larger drums, simplified hydraulic drives, specially designed continuous corrugated neoprene rubber grip belts, and added power as well as the newly developed gathering-conveying improvements of the earlier machine are all features of the new harvester-ribboner. The unit successfully harvested 5 acres of kenaf from mineral soils and 25 acres from the peat soils of the Everglades. Needed improvements were noted and most of these have been made in preparation for similar acreage testing.

Oilseeds and Peanut Harvesting Equipment. Harvesting the tung crop by the present method of hand gathering is the major cost in production. A complete harvester was designed, constructed, and operated successfully harvesting 60 acres of well-prepared land with very low field losses. The machine is mounted onto a tractor and utilizes the tractor three point hitch for carrying a 1,000 lb. capacity low cost pallet-type box. Features include making its own windrow or picking up one made by other machines, removal of loose leaves and sticks, and delivery of cleaned fruit to a box mounted onto the tractor. The capacity of the harvester averaged about two tons cleaned fruit per hour. The removal of leaves using a large rotating

perforated barrel set at an incline with a large volume of air blown upward through the barrel permitted separations not previously obtainable with other types of cleaners. A large portion of the sticks were also removed by the conveying system. Several tests showed the harvested fruit to have 3.3 percent foreign material.

A self-propelled windrower is needed to speed up tung harvesting operations where tree row width and/or low yields would result in operating the harvester at partial capacity on a small windrow. A windrower employing rubber fingers mounted as a helicoid on a cylinder was built and operated satisfactorily on 60 acres. This extremely maneuverable machine is built low to operate near tree trunks. Future studies will be to develop a blower on the windrower to clean out the tree row. This is needed to replace hand raking in the tree row area.

A bulk handling system for reducing costs and labor requirements of tung is needed to facilitate mechanical harvesting. Wooden wire-bound pallet type boxes were designed to have one side panel hinged which could be readily unlatched for dumping. The boxes which have a capacity of 1,000 lbs. of unhulled tung are picked up and hauled from the harvester and dumped into a trailer at roadside using a fork lift on a tractor. This system of handling harvested tung fruit required only one man on short hauls. Constant use of the boxes indicated certain structural weakness, however.

Defoliating castor beans as a means of conditioning to harvest is needed to lengthen the harvest season and to permit earlier harvest at a time when good weather is normally experienced. Past grower experience has shown defoliation with chemicals to vary in effectiveness when used at different times of the season. Defoliation studies were initiated in 1961 in cooperation with ARS, CRD, at Davis, California. A commercial high clearance sprayer was modified to include features for applying chemicals under a wide range of conditions suitable for field plot research. One year's results on both dwarf and normal internode plants showed the use of 1 quart Diquat with 20 gal. water and an activator applied at the rate of 20 gal. per acre gave effective drying and conditioning of castor plants from August 23 through October 6. Later defoliation applications were not made due to wind loss of seed from the plants. Defoliating castor beans before September 21 prevented some of the spikes from maturing and consequently reduced yields and test weight.

Lower cost, more efficient castor harvesters suitable for use at high ground speeds are needed to increase growers' returns. Field loss studies on two current commercial model castor harvestors showed the major loss to be from the header. This amounted to 4.6 percent at 1.4 miles per hour and increased to 11.9 percent at 4.8 miles per hour. Improvements made to simplify castor harvesters which included

sloping of the row brushes across the row, removal of one auger per row, and relocation of the rotating knockers resulted in two manufacturers incorporating these principles on their production machines.

An inertia-type beater employing high frequency low impact action was designed and built onto a castor bean harvester for the purpose of investigating more effective methods for removing castor bean capsules from standing plants. Brief tests in late winter showed the beater design has insufficient lateral movement for the mechanism to contact all plants, particularly those leaning out of the row line.

Two-drum hullers used on castor harvesters usually leave more capsules unhulled than other type hullers but have the advantage of operating without requiring precleaning to remove sticks and trash. Basic studies were made to evaluate factors affecting drum huller performance using a wide range of drum speeds, rates, and clearances. An analysis of tests showed that feed rate had no significant effect on the percentage of seed broken or the percent of oil bearing material removed in the trash. High feed rates caused significantly more unhulled seed than low feed rates. Drum clearance was found to have the most significant influence of the variables tested. Small clearances caused significantly more broken seed and significantly more oil bearing material in the trash sample than large clearances. Large clearances resulted in significantly more unhulled seed and also significantly reduced the rate of hulling. Because of the large percentages of broken and unhulled seed, drum hullers of a size used in this study need further development to be of optimum value on field harvesters.

Oily residue build-up on bulk conveying and harvesting equipment at temperatures of 60° F. or lower resulting from broken and oily castor seed will result in added seed breakage, also stops for clean out, and a decrease in conveying capacity. Previous studies showed conveyor housing temperatures of 100° F. were required to prevent build-up at low outside temperatures, although build-up did occur on the auger flighting. Current studies of heating the auger flighting with heating cable attached to the underside resulted in the auger remaining clean of residue build-up when kept at a temperature of approximately 90° F. at a time when outside temperatures were in the 40's.

A machine suitable for plot harvesting was designed and built as a research tool for the Agronomists to assist in developing improved varieties of castor beans better suited for mechanical harvesting.

Performance tests on a relatively simple low capacity huller-cleaner recently developed on the project for use on small scale or foreign country hulling operations showed that power requirements exceeded

what could be sustained by manual operation. Effective cleaning was obtained at a feed rate of 500 lbs. per hour. The use of a positive air cleaning system instead of negative air cleaning employed in the present huller showed more effective cleaning.

Digger-shakers in common use result in losses of peanuts separated from the vines during digging. In addition, only a partial removal of soil from vines reduces the field drying rate. Further development studies on an experimental digger-shaker consisted of redesigning, increasing the number, and relocating elliptical-shaped kicker wheels that would permit more effective soil removal from the vines. Digging blades were widened and designed to cover the full width of two rows. Field tests showed recovery yields were higher on the experimental digger as compared to the conventional diggers. One hundred forty-four lbs. more peanuts per acre with a value of \$15.00, and 305 lbs. more peanuts per acre with a value of \$30.40 were obtained on two separate farms.

Accelerating the rate of field drying of peanuts by reducing the number of days exposed to the weather can mean material savings to the grower in peanuts saved, as well as quality retained, particularly during wet harvest seasons. Experimental methods to achieve a faster field drying rate of peanuts were continued. The percent of moisture remaining after 6 days of favorable drying weather in the windrow for methods tested was as follows: placing windrow on a vapor barrier sheet, 20 percent (W.B.); windrowed with nuts up, 24.9 percent; windrowed with nuts mixed in windrow (conventional method of digging and shaking), 27.8 percent; clipping vines with rotary cutter, 27.8 percent; dessicant applied to vines, 28.6 percent; windrowed with nuts down, 30.1 percent. Optimum moisture content of peanuts harvested from windrows is considered to be approximately 8 percent.

Potato Harvesting Equipment. A three-year study of the effects of secondary pre-plant tillage practices on harvesting was completed. The experimental treatments were applied on land that had been either in summer fallow or in small grain the previous year with the stubble plowed down in the fall. An important conclusion of this study is that there is no advantage to be gained by pre-plant tillage in the spring. The results of the study of secondary pre-plant tillage practices indicated that an investigation of the effect of primary tillage (plowing or other initial soil loosening operations) upon the production of potatoes could yield valuable information. An experiment was designed for application on unplowed wheat stubble in the fall of 1960. The results of the one-year trials showed that fall plowing deep tillage in the spring, deep tillage in the fall, or no tillage did not influence yield of potatoes, digger draft, or amount of clods.

Four-row and six-row potato harvesting operation. A new windrower was designed, constructed, and tested which makes it possible to deliver a two-row windrow to a position between two adjacent dug or undug rows and makes it possible to harvest four and six rows of potatoes with a harvester.

Spillout losses and blades in potato harvesters. A study of the location of individual tubers of Kennebec, Norland, and Pontiac varieties showed that 98 percent were located in a band 16 inches wide and 100 percent in a band 20 inches wide. Therefore, spillout with the conventional 26-inch wide harvester is due to lateral migration of tubers ahead of the apron. Studies showed that open-front style harvesters with twin rotary rod shares were entirely practical for harvesting potatoes. The amount of clods was not increased and spillout was reduced. Results also showed clod deflector shovels in combination with rotary rod shares reduced spillout losses.

Mechanical Injury of Potatoes. Instruments were developed to investigate the force and deformation relationships of potato tubers and determine whether these physical relationships could be correlated with susceptibility to injury from impacts or pressures. Preliminary results gave little encouragement that force-deformation will prove to be an easily applied measure of injury susceptibility. A series of tests were conducted to measure the electrical conductivity of potato tissue. There proved to be no conclusive correlation between these measurements and susceptibility to mechanical injury. A simple impact instrument was designed and constructed and used successfully in measuring the susceptibility to injury of potatoes. This instrument may be extremely valuable as a simple commercial instrument that can be used by potato growers to estimate the degree of injury that should be anticipated in harvesting and handling a given lot of potatoes at a given time. Production design and experimental links for harvester apron chains are being studied as to their effect on bruising potatoes. No conclusions have yet been reached.

Time Losses in Mechanical Harvesting of Potatoes. A study of amount of time lost and reason for breakdowns in harvesting potatoes mechanically showed that proper planning and management could eliminate many of the delays. The main reasons for delays were improper field layout, improper maintenance of equipment, and lack of planning for emergencies.

Sugarcane Harvesting Equipment. The USDA experimental sugarcane harvester research was continued in Louisiana. Changes consisted mainly of stripper development and evaluation, also redesign for better trash disposal and control. These studies are in cooperation with the American Sugar Cane League who provided both technical guidance and financial assistance.

Effective trash removal and low maintenance cost of the harvester stripping components are two most important requirements needed for industry acceptance. Evaluation of wear resistance and durability of materials for strippers was made on a laboratory torture machine and field harvester. On the torture machine bamboo was found too brittle, while nylon, teflon, and wire core belting failed in less than 22 hours from excessive wear. Under field conditions spring steel failed to retain its elasticity and broke from fatigue, while the rubber mounted spring steel stripper broke at the rubber mounting from lack of flexibility and the steel sash chain and links failed from excessive wear. No replacement or failures were encountered with No. 2/0 case hardened twist link chain during a 300 ton field test. The molded rubber strippers showed wear after 31 hours of torture test. In field tests, 27 of the rubber type strippers were replaced while harvesting 1,370 tons cane. The chain type strippers shredded the cane leaves more than the rubber strippers, making it more difficult to separate loose trash from the cleaned canes.

Stripper action studies on the torture machine through use of high speed motion pictures showed sash chain collapsed upon impact and bounced away from the material that would be stripped, whereas the twisted link chain flexed at the end links but maintained contact. Molded rubber strippers flexed sidewise as well as backwards upon impact but maintained contact.

The machine performance for 2,393 tons of cane harvested during the entire season showed an average trash content of 5.5 percent compared to 7.2 percent for conventional cutting, burning, loading method of harvesting. A maximum capacity of 167 tons was obtained in 7 2/3 hours while operating at 1.9 m.p.h. Lack of adequate harvester engine power prevented high operating speeds. In addition, axle failures showed this assembly was not strong enough for the harvesting requirements. Accumulation of loose cane trash along the cane carriers required frequent removal by hand to prevent chokes. Greater clearance is required in the cane passages for the separation of trash from cane. A progress report on this harvester development is being published.

The adaptation of a gooseneck assembly to the conventional sugarcane cart increased the hauling capacity per unit from 2 1/2 to 4 tons and permitted direct loading with the USDA experimental sugarcane harvester. Further modifications of the cane cart body will increase the capacity to 5 or 6 tons. The conventional sugarcane cart can be converted at a total cost per wagon of about one-fourth the original cost of the special 6-ton capacity wagons. Under normal operating conditions, five to six wagons and three tractors are required for the continuous operation of the experimental sugarcane harvester.

Tobacco Harvesting Equipment. Present methods of producing burley tobacco require approximately 400 man-hours per acre, and therefore result in high production costs. International competition in the tobacco market has increased the need for new methods that provide economic advantages for producers in this country. This project, activated in June 1961, is designed to determine principles involved in harvesting burley tobacco in order to develop methods and equipment for mechanical handling of this crop.

One phase of this project is to describe tobacco plants in engineering terms which can be used for machine design. Six physical properties of mature burley plants have been studied in the laboratory: (1) taper of stalk, (2) location of leaves, (3) leaf dimensions, (4) moisture content of the stalk, (5) weight of stalk, and (6) weight of leaves. It was found that the taper of the stalk could be approximated by the equation $R = -0.00587 D + 0.8$, where R is the radius of the stalk and D is the distance above the first node (inches). The leaves were spaced approximately 2 inches apart in a zone from 10 to 25 inches above the base of the stalk. Below that zone the spacing decreased and above that zone the spacing increased to an average of 3.5 inches at a height of 4 ft. above the base. The moisture content of the stalk was determined to range from 78 percent at the base to 86 percent (wet wt. basis) at the top.

A second phase of this project is the development of a mechanical tobacco harvester to cut tobacco plants, pierce the stalks and place them on conventional wooden sticks with 6 plants per stick. This is a project initiated by the Kentucky Agricultural Experiment Station in 1960, in which ARS personnel are now cooperating.

The machine has been built in four components--(1) a cutting unit, (2) a spearing unit, (3) a stalk spacing or stick filling unit, (4) a stick dispensing unit--each of which is designed to meet its specific functional requirements in the harvesting process. The first of these units was completed and added to the other three which were built and laboratory tested last year. These four hydraulically driven and controlled components were placed within a frame and suspended from a modified high clearance tractor. The machine was put through laboratory tests, which included high speed photographing of various mechanical movements for future analysis. Also, limited field tests were conducted in 1961. These tests indicated that with the elimination of minor difficulties the machine will meet its design capacity of 36 stalks of burley tobacco evenly spaced on six sticks per minute.

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AREA #5 CROP PREPARATION AND FARM PROCESSING
(EXCEPT COTTON)

Problem. The programs of research in this area are concerned with the development of better methods, techniques, and equipment for use on farms for the initial preparation for market or the processing of farm products to increase efficiency in the use of labor and equipment, preserve quality and prevent spoilage and damage from mechanical handling. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes before development progress can be continued. The underlying principles that pertain to the cleaning and drying of different crops, curing of tobacco and peanuts, and sorting need to be determined. The methods for processing farm crops are largely dependent on production practices and dictated by future handling or storage requirements. Consequently this requires interdisciplinary collaboration in the creating of a completely mechanized program of crop production.

USDA PROGRAM

The Department's effort in this area constitutes a long-term program involving agricultural engineers and statisticians engaged in both basic and applied research on the engineering phases of crop preparation and farm processing. Seed cleaning research is currently being conducted at Corvallis, Oregon, in cooperation with the Experiment Station and private industry. Research on tobacco curing and sorting is cooperative with the Experiment Station at Lexington, Kentucky. The decor-ticating, retting, and cleaning of long fiber crops is carried on at Belle Glade, Florida, in cooperation with the Everglades Branch Experiment Station, the Office of Defense Mobilization and industrial fiber users. Research on the drying of grain is cooperative with the Experiment Station at Ames, Iowa, equipment manufacturers and farmers. Forage drying is under study at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Coastal Plains Experiment Station. Manufacturers cooperate through loan of drying equipment. Research on the drying and hulling of tung nuts is conducted at Bogalusa, Louisiana, in cooperation with the Experiment Station and industry. The pelletting of forage crops research is conducted at Tifton, Georgia, in cooperation with the Coastal Plains Experiment Station and equipment manufacturers.

The Federal engineering effort devoted to research in this area totals 10.6 professional man-years. Of this number 2.1 is devoted to seed cleaning, 2.0 to curing and sorting of tobacco, .3 to decorticating, retting and cleaning long fiber crops, 4.0 to drying of grain, .5 to drying forages, .2 to drying and hulling tung nuts, 1.0 to pelletting forage crops and .5 to program leadership.

RELATED PROGRAM OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 21.4 professional man-years divided among sub-headings as follows: seed cleaning .8, curing of peanuts 1.1, curing and sorting of tobacco 2.0, drying of grain 4.9, drying of rice .5, drying of forages 8.5, farm drying, curing and packaging of deciduous fruit .1, farm drying, curing and packaging of vegetables .3, and pelleting of forage crops 3.2. Seed cleaning research is conducted in the North Central and Southern Region. Curing and sorting tobacco is under study in the North Central, Northeastern and Southern Regions. Research on curing of peanuts, drying and hulling of tung nuts, and drying of rice is conducted in the Southern Region. Drying of grain and forages is under study in all four regions. Research on pelleting of forage crops is conducted in the North Central, Northeastern and Southern Regions. The farm drying, curing, and packaging of deciduous fruits and vegetables is under study in the Western Region.

Industry and other Organizations concerned with crop preparation and farm processing devote their research effort to equipment and methods for use in the fields of drying, seed cleaning, tobacco curing and pelleting. Both full line and small manufacturers cooperate in USDA research through loan of equipment. Since industry relies primarily on public agencies for basic research in this area, considerable interest, encouragement and cooperation is given by industry. Farmers and organizations furnish crops, equipment and facilities for experimental use. Estimated annual expenditures are equivalent to approximately 50 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Seed Cleaning. At Corvallis, Oregon, a satisfactory fluidized seed conveying system that will transport seed without damage, yet which can be quickly cleaned between lots, has been developed and tested. Basic engineering data such as air movement, seed velocities, conveying rates, feeders, air-solid ratios, pipe sizes, and other pertinent information necessary for the design of a commercial system, have been collected. Seeds which have been conveyed through the 60-foot system of 1 1/2-inch diameter pipe are beet, parsnip, castor beans, peas, and lentils. Studies have also included the conveying of beans at a series of velocities in both lean and dense phases to determine relative conveying capacities and seed damages. The data have been compiled and curves plotted for inclusion in a technical bulletin.

Conditioning seeds which are difficult to clean, handle and plant. Research was conducted on some 50 problem seed mixtures that are difficult to separate. Laboratory reports were prepared and recommendations made to the seed processors as to the methods and machines used for best separating results. The scientific approach to seed

measurements has resulted in a practical method of selecting the machine and the type and size of indent or screen to be used. Laboratory microscopic measurements of seeds and their contaminants are used to dictate processing sequence with predictable seed losses and purity, thereby materially reducing processing costs and seed losses.

The technique of installing periodic screen dams was effective in the following separations: Ryegrass from creeping red fescue, hairy chess from Alta fescue, quackgrass from Chewings fescue, rattail fescue from creeping red fescue. Another technique was the use of electrically produced vibrations of an inclined textured surface deck as a separator. Problem mixtures that responded to this technique were rumex from white clover, dodder from carrot, wintercress from timothy, pigweed from Ladino clover, velvetgrass from Merion bluegrass, pigweed from geranium, and hulled Bermudagrass from Dutch white clover. A multideck semi-commercial size unit was developed and tested with good results. Recommendations are available for a full-size commercial machine construction.

A catapult unit was constructed to explore air resistance of seeds propelled through air. Problem seed mixtures were energized by the unit. If there is a significant difference in the travel distance of the seeds, a machine will be developed to make the separation.

Centrifugal-pneumatic separator for seeds. There was no research conducted on the centrifugal-pneumatic separator during this reporting period. The plan for future work is to use a vacuum in lieu of air pressure as a means of removing the lighter seed from the revolving screen.

Modification of seed-length separators. A survey of commercial indent sizes and microscopic measurements of problem seed mixtures indicated that more precise diameter and depth indent pockets would separate many of the seed mixtures on their differences in length. This was particularly true in the smaller sizes with a complete void in the bentgrass range. This study resulted in the development of special indent cylinders of the proper size for a specific separation of a number of problem samples. Special indents were made, based on data obtained in microscopic measurements of the contaminants, and tested with good separating results for the following mixtures: pigweed from alfalfa, Johnson grass from alfalfa, yellow cress from bentgrass, cocklebur from cottonseed, big mouse-ear from bentgrass, toadrush from bluegrass.

Development of vibratory feeders for use in studying seed cleaning and handling machinery. Adjustable constant-flow feeders or metering devices are a necessary part in the proper operation of seed cleaning and conveying equipment. Expensive electro-magnetic feeders are being satisfactorily used in the laboratory to supply seed to the many laboratory working models and inspection stations. However, the expense of these

units is discouraging the adoption of prototype machines for use in seed testing. Therefore, mechanical vibrators, using inexpensive fraction-horsepower motors to drive a cam by means of a rubber-band belt, have been developed that can be secured for about one-seventh of the cost.

Tobacco Curing. A need for reducing the high labor requirements and cost of producing burley tobacco has stimulated research efforts toward mechanization of the crop. In this project, initiated in June 1961, the curing phase of tobacco production is outlined to investigate methods and develop principles for curing facilities that will be compatible with the overall system of mechanized tobacco production. In one sub-project, an objective is to study the effect of controlled environmental conditions on the mass and energy exchange of curing tobacco with its surrounding environment. The approach is to define curing in engineering terms and develop a mathematical expression relating mass and energy exchanges of the curing tobacco as a function of controlled environmental conditions. The proposed benefits of this study will be to obtain basic information and further knowledge of curing which may be used in the design and development of prototype curing facilities.

The results of a very simple preliminary lab experiment the past season showed that a single mature leaf sealed in an airtight container (plastic bag) and kept at a room temperature of 75° F. depleted the oxygen in the container from an initial concentration of 20.9 percent (atmos. air) to a cumulative 10.9 percent in a period of one week. The carbon dioxide accumulation amounted to 8.8 percent in the same period. The simplicity of the equipment did not permit control of the relative humidity in the container, measurement of the weight and moisture losses, nor measurement of the total volume of air or gas during the short period of curing. By the end of one week, undesirable biological activity had destroyed this and similar other samples.

Curing of burley plants in loose bulk. The objective of this investigation was to determine the feasibility of curing intact burley plants in loose bulks. This method would eliminate the need for spearing the burley stalks and placing them on sticks, thus reducing the amount of hand labor for housing the tobacco. Another advantage would be to reduce the size of the curing structure. In a series of laboratory tests air static pressures, bulk densities and drying rates were determined. Initial static pressure gradient, from base to tip of the plant, in a bulk of 12 lb/ft³ density (15 plants/ft²) for an air flow of 80 cfm/ft² was about 0.16 inches of water/ft. Controlled drying rates were about 1.5 percent/hr (dry wt) for the first 80 hours and increased to about 3.5 percent/hr for the next 200 hours. The bulk drying occurred in a front which advanced in the direction of air flow. The leaves and stalks dried simultaneously. Acceptable burley was cured in this manner in 10 to 12 days.

Decortivating, Retting, and Cleaning of Long Fiber Crops. The work on improving processes and techniques for cleaning ramie ribbons during the past year has been concerned primarily with testing the improved harvester-ribboner which makes a cleaner ribbon and with investigating the burnishing, stapling, and degumming of these ribbons by standard processes. The 3 1/2-acre planting at the Everglades Experiment Station has been used for all of the test material. Most of the degumming tests have been made by station cooperators who are doing extensive research along this line. Substantial progress has been made in field ribboning. A manuscript on ramie harvesting and processing equipment is being published.

The project for developing brush bristle fiber decortivating equipment and methods has expired and will not be renewed as such. The decorticator and allied crushing equipment performed up to expectations, but did not compete with Mexican fiber that was dressed by low cost labor in Mexico. Development of an industry from the crude chemicals in the decorticator waste has not materialized although there is some interest in West Texas and by firms in Chicago.

Due to the urgency of kenaf equipment development work, no progress was made on defibering and fiber conditioning machinery and methods for sansevieria.

Cleaning equipment for kenaf. A double groove roll for the rope conveying system of the squeeze rolls was installed and the second scutching unit of the washer built. Corrugated rubber belts were installed in each scutching unit. All of the fiber from the above areas was cleaned on this equipment. Approximately 10 tons of fiber were shipped to spinners for manufacturing tests.

Tests showed the fiber good in blends and coarser yarns, but improvement is needed in strength and decreased brittleness for the finer count yarns of 100 percent kenaf. Spinners have urged expansion of the project to give them larger samples.

Drying of Grain. With the help of the Weather Bureau, maps of the United States have been prepared showing the average wet bulb temperature and average wet bulb depression for each month of the year. The available data is now in a form that can be used for grain drier design and operation. The maps are completed but not yet published. It is expected that they will be published by ASAE. The maps also show the standard deviations so that the designer can estimate the probable deviation from the average. The data were from about 200 Weather Bureau Stations and cover about ten years of observations. Records for earlier years are too fragmentary to be useable for this purpose.

Tests on the counterflow drying of grain were completed. They included tests on corn, oats, wheat, and grain sorghum. In a counterflow process each kernel leaves the drier when it reaches the desired final moisture as contrasted with a typical batch drier in which some kernels are overdried and some underdried when the average moisture content has reached the desired level. In counterflow drying, all of the grain reaches the same temperature. For these reasons higher air temperatures may be used before heat damage or overdrying damage occurs than in a conventional drier. Grain sorghum germinated after drying at air temperatures of 150° to 160° F. whereas with a conventional drier the highest temperature that may be used safely is about 110° F. Additional germination tests on sorghum and corn dried in a counterflow drier have been completed. These results show conclusively that the rate of moisture removal by itself is not the cause of loss in germination. In counterflow drying the rate of drying of each kernel is almost constant throughout the drying period. Germination is lost if the conditions are such that this constant rate of moisture loss is continued too long.

Reabsorption of moisture by dried grain. Preliminary studies have shown that expansion from reabsorption of moisture by dried grain resulted in pressures which burst a wooden test bin. In a steel bin test, slippage of the bin sheets at lap joints allowed the bin to absorb the increased pressure without other failure. Additional tests are needed to determine the life of steel bins subjected to repeated rewetting tests. With absorption of moisture in the grain, the vertical pressure on the wall reverses direction and the grain tends to lift the wall. The depth of the wetting zone in the grain in such a bin is far greater than the corresponding drying zone in grain which is being dried.

Time limits on in-storage drying of grain. Study was continued on the rate of deterioration of grain in model drying bins by measuring the rate of CO₂ production. Mechanical damage to the grain increases the rate of spoilage greatly. The number of variables and the limited season during which naturally wet grain is available makes the accumulation of data very slow. A new technique by which a much larger number of tests may be made simultaneously has now been adopted. It consists of measuring the accumulation of CO₂ rather than the rate of production and reducing the size of the model bins so that tests can be run in laboratory flasks. It appears that the difficulties in making such small samples duplicate full scale drying bins have been solved. Current studies in 48 such bins or samples have been completed. Corn at six temperatures and four moisture contents was tested. It appears from the results that it may be possible to distinguish between the respiration of the grain itself and that of the micro-organisms infecting it, and that these two sources of deterioration are influenced differently by changes in temperature or moisture. It was found that with corn moisture content at 22 percent or above, the deterioration rate could be measured with satisfactory accuracy.

Drying Forages. Drying of stored alfalfa wafers either by artificial means or by good natural ventilation was again shown to be necessary to eliminate molding, even when the hay was sufficiently dry for safe baling. On the other hand, over-dried wafers had poor durability and partially disintegrated in handling. The moisture content for safe storage appears to be about 14 percent. Handling wafers, especially moving out of drying bins or storage, was difficult because the wafers were not free flowing. Until wafers are made to be free flowing, handling advantages are not apparent. However, handling properties of wafers produced by each make of machine differ and will be further investigated.

Drying and Hulling of Tung Nuts. Tung is grown in a high rainfall area and this often results in prolonged periods of wet weather before the crop is harvested. Studies using an experimental drier were continued to determine the economic aspects and requirements of artificially conditioning tung fruit for safe storage on the farm. Elimination of air channeling and uneven drying was overcome only when tung fruit had all leaves, trash, and dirt removed. Additional basic data is being accumulated to assist in establishing the relationship of tung moisture content to drying requirements; moisture removal rate per unit of air flow; tung depth resistance to air flow, etc. These studies are to be continued.

Pelleting of Forage Crops. Studies with Coastal bermudagrass showed that pelleting coarse material resulted in lower production rates and required more energy than when fine material was handled. However, fine grinding required more energy than coarse. When grinds of 1/4-inch and less were pelleted in a 3/16-inch die, there were no significant difference between grinds in the total energy of the two operations. The lower pelleting production rate of the coarser material apparently is due, in part, to the low feed rate of the bulky material. Thus, it appears that a redesign of the feeder and geometry of the die opening might increase the pelleting output of coarsely grown material and thus substantially reduce operating costs.

The use of binding agents in Coastal bermudagrass pellets showed very little effect on pellet quality. Although sufficient water was added to bring the moisture content of the Coastal bermudagrass meal to about 17 percent W. B., the binding agents apparently were not sufficiently activated.

Grinding and pelleting energy studies on new forage hybrids indicate some differences exist between these hybrids. This work is cooperative with the Forage and Range Research Branch and the information obtained will be used in the development of hybrids which will have high processing efficiency as well as high yield, quality, etc.

Feeding trials with Coastal bermudagrass pellets showed these pellets or pelleted mixtures can be used successfully in a steer fattening program. Although steers receiving 100 percent Coastal bermudagrass pellets had an average daily gain of 2.01 pounds and a feed conversion ratio of 11.2:1 which compared favorably with 2.26 pounds and feed conversion ratio of 9.9:1 for the steers receiving a pelleted mixture of 50 percent corn and 50 percent Coastal bermudagrass, they did not have the finished quality of steers which received corn in the mixture. These results are similar to those obtained with ground snapped corn thus before pellets can be economically used, they will have to become competitive price-wise.

Wafered alfalfa hay. Physical characteristics of wafered alfalfa forage were measured by using certain improvements and modifications of ASAE standards. Bulk densities ranged from 20 to 25 lbs. per cubic foot with one-third the volume of bulk wafers being void. Fines partially filled these voids to increase the bulk density. Of the two field wafering machines observed, both made dense, self-binding wafers, but only from legumes having less than 20 percent moisture (W.B.). Grassy materials could not be wafered.

Wafers fed to dairy cattle produced small but significant increases in milk production when compared to production from dairy cattle fed baled hay. However, total animal yield per acre may be lower for wafers than other forms of artificially dried or ensiled forage since the prolonged field exposure necessary to obtain sufficient dryness for wafering causes quantity and quality losses.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Seed Cleaning

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- Klein, L. M., Henderson, J., and Stoesz, A. D. 1961. Equipment for Cleaning Seed. Yearbook of Agriculture, pp. 307-321.
- Purdy, L. H., Harmond, J. E., and Welch, G. B. 1961. Special Processing and Treatment of Seeds. Yearbook of Agriculture, pp. 322-329.

Decorticating, Retting, and Cleaning of Long Fiber Crops

- Byrom, M. H. and Whittemore, H. D. 1961. Long Fiber Burnishing, Ribboning, and Cleaning Machine. ARS 42-49, March.

Drying of Grain

- Hukill, W. V. 1960. What We Know and Don't Know About Grain Drying. Grain and Feed Journals, Vol. 117, No. 20, October.
- Hukill, W. V., Saul, R. A., and Teare, D. W. 1960. Outrunning Time; Combating Weather. Yearbook of Agriculture, pp. 183-189.
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AREA 6, COTTON GINNING

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed and trash, packaging, and sampling to preserve the inherent qualities of the end products. This is the final operation in the process of cotton production since, subsequent to ginning, title to the lint and seed passes from the producer and the products enter the market channels.

Advances in cultural practices in the mechanization of cotton harvesting will depend to a great extent on continued research to develop adequate ginning equipment, improvements in present equipment, and improved practices in using equipment. The solution to many of the difficult problems of modifying the gin to meet the needs of mechanically harvested cotton are still ahead.

Cotton ginning problems are greatly influenced by the recent increase in mechanical harvesting on one hand and the desire of the spinners to increase their manufacturing efficiency on the other. Since it is recognized that the present day seed cotton comes to the gin containing more trash and moisture than formerly, it follows that conventional ginning processes cannot be expected to deliver to the industry a product with the same qualities that characterized the cotton of former years. A close analysis will show that the most pressing problem areas with regard to ginning are those pertaining to controls for drying and equipment for cleaning both the seed cotton and lint.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, materials engineers, and systems engineers engaged in both basic and applied research on the engineering phases of cotton ginning and handling. Seed cotton handling and storage is currently being conducted at Stoneville, Miss.; Clemson, S. C.; Mesilla Park, N. Mex.; and Chickasha, Okla. Research on seed cotton drying, seed cotton cleaning and gin performance and cotton quality is conducted at Stoneville, Clemson, and Mesilla Park. Conveying equipment and gin waste disposal studies are conducted at Stoneville and Mesilla Park. Packaging research is underway at Stoneville and Clemson. Lint cleaning studies are conducted at Stoneville, Clemson, Chickasha and Mesilla Park. Research on gin stands is carried on at Stoneville, Chickasha, and Mesilla Park. Equipment requirements for cottonseed drying, cleaning and storage are studied at Stoneville.

The Federal engineering effort devoted to research in this area totals 19.0 professional man-years. Of this number 2.2 is devoted to seed cotton handling and storage, 2.7 to seed cotton drying equipment, 1.3 to seed cotton cleaning, 1.0 to conveying equipment, 3.1 to gin stand, 0.8 to packaging, 3.9 to gin performance and cotton quality, 2.3 to lint cleaning, 0.5 to cottonseed drying, cleaning and storage, 0.7 to gin waste disposal and 0.5 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 1.9 professional man-years which was devoted to research on gin performance and cotton quality. These studies were conducted in the Southern Region and contribute to Cooperative Regional Project S-2.

Industry and other organizations conduct engineering research on equipment and methods for cotton ginning. There are five companies that manufacture a complete line of gin plant machinery and perhaps four others who make accessories. Practically all companies cooperate in USDA research through loan of equipment. Estimated annual expenditures are equivalent to approximately 15 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Seed Cotton Handling and Storage. At Clemson a test was conducted to determine (1) the effect of high moisture green foreign matter in seed cotton on color as determined by the Colorimeter and on fiber properties, and (2) if chlorophyll stain can be detected in cotton after long contact with green matter of high moisture content. The tests showed no visual evidence of chlorophyll stains being present on fibers after a 13-week storage period during which high-moisture green foreign matter was in contact with seed cotton having an average initial moisture content of less than 12 percent.

At Stoneville a report was prepared covering a seed cotton storage project and is in the process of being published.

Seed Cotton Drying. Tests at Stoneville showed that although bench model vacuum drying of lint without supplementary heat showed promise in 1961, the adaptation of the apparatus for drying seed cotton for ginning was not successful.

As the vacuum system approached its lower pressure limit of 4-7 mm Hg., it also approached the saturation vapor pressure of moisture at the system temperature. This effectively decreased the drying rate to practically zero.

Moisture equilibrium tests at Stoneville using seed cotton, lint and seed from the same stock showed equilibrium moisture contents for all three components to be less than one percentage point apart in the range 11 to 77 percent relative humidity. At 93 percent relative humidity moisture contents of lint, seed cotton and seed were 15.2, 16.6, and 18.5 percent, respectively. The mass of seed--approximately two-thirds of seed cotton mass--and its moisture content at equilibrium was shown to be more influential than the moisture content of lint in determining the percentage moisture content of seed cotton at moisture equilibrium. These tests showed the percentage moisture content of both seed and lint to be 6.75 at 57 percent relative humidity with lint having a higher equilibrium moisture content than both seed and seed cotton at relative humidity lower than 57 percent. At relative humidities above 57 percent seed and a higher equilibrium moisture content than lint. This tendency became more pronounced as relative humidity increased.

Tests at Mesilla Park showed that differences in lint moisture contents for three commercial cottons were found to be significant at the 10.0 percent confidence level. Differences in lint moisture contents within each breeder's group of strains were not significant; however, the average contents of two groups of upland strains were higher than the average for American-Egyptian fibers that had been conditioned at the same relative humidity.

Moisture removal versus quality tests at Clemson showed that there is very little difference in fiber properties caused by bringing cottons of varying moisture content to 6 percent by various combinations of heat and exposure.

It is apparent from tests at Mesilla Park that if the initial moisture content of the cotton were known and all the drying conditions could be accurately measured and/or controlled the amount of drying could be predicted. This study pointed up the need for more accurate measurements of air flow, temperatures in the air-cotton mix during processing, specific heats of seed cotton, seed and lint, and the moisture contents of the cotton. There was evidence in the study that additives such as textile oils may change the drying characteristics of the fiber.

A by-product of this study of a standard tower dryer was a small investigation of the probability of ignition of cotton at 8 percent average moisture content during drying with entering air temperatures below 500° F. Although scorching in the tower dryer occurred in moving air at temperatures below 500° F., no ignitions were detected in air below 600° F. Definite temperature ranges were not determined and exposure times were confined to the range of from 3 to 90 seconds. These temperatures were measured just prior to mixing the cotton with the air. A sharp temperature drop takes place in the drier when the cotton and air are mixed.

Studies of temperature drop at Clemson indicated the temperature of the air at any point in the drying system could be predicted with a high degree of accuracy when the temperature of the air at one point in the drying system was known.

Bench tests using high temperatures. Work at Stoneville using wax extracted from lint showed that gin drying temperatures usually exceed the melting point of cotton waxes (158° F.). Pressley strength tests on natural and dewaxed lint showed the dewaxed fiber to be slightly stronger than the natural cotton.

High temperature studies at Stoneville on ginned lint showed that initial moisture (within the range 3.5 to 12.5 percent) appeared to have a negligible effect on time required at 450° F. to scorch cotton. Less than two seconds at 450° F. will cause scorching. Temperatures of 360° F. and 400° F. required exposures of 30 to 15 seconds, respectively, to cause scorching. Charring did not occur at 360° F. but did occur at 400° F. after three minutes. Lowest ignition temperature observed was 450° F. after 37 seconds exposure. Progressively longer exposure periods were required at this temperature for cottons of progressively higher moisture content. Sixty-five seconds at 450° F. ignited lint of 12.5 percent moisture content. At 550° F. scorching was instantaneous, charring required two to five seconds and ignition required 17 to 23 seconds using lint in the 4.5 to 8 percent moisture range. Tests on seed cotton gave similar results. Cotton which was moisture saturated charred at 500° F. in 10 seconds but had not ignited after six minutes exposure.

Microscopic examination of heat-dried cotton showed more tight kinks than undried cotton. These kinks are presently regarded as points where fiber fracturing is more likely to occur than at unkinked portions of the fiber.

Drier development. Tests at Stoneville showed that conventional driers cannot be adequately controlled. Investigations of heating and cooling rates of present gin driers showed the air-cotton mix-point temperature to closely follow the action of the gas input valve, but the drier exit temperature required 8 minutes and longer to approach stabilization.

Since the conventional drier responds too slowly for use in any practical drier control system, a drier which would give instant response was developed. This multi-path drier has proved to be very effective in synchronizing the degree of drying to coincide with variations in the moisture content of cotton.

A moisture and temperature measuring system for continuously monitoring the fiber of seed cotton and lint moisture at various points in the gin plant was tested at Clemson. Results indicate that the system is capable of measuring the lint moisture continuously with a high degree of repeatability. The quantity of foreign matter in the cotton in combination with a foreign matter moisture content in excess of equilibrium does affect the results. Also pieces of foreign matter large enough to bridge the sensing electrodes will cause erroneous readings.

An electronic moisture measuring system developed at Stoneville was subjected to extensive tests. The system was found to be capable of controlling the multipath drier described under "Drier development." Drying tests with the system operating fully automatic at a pre-set temperature of 200° F. would dry cottons ranging from 10 to 15 percent moisture to the recommended level of 5 to 7 percent by controlling the exposure time in the drier. This system together with a multipath drier has been turned over to the industry.

Pilot plant study. A ginning-spinning test in cooperation with the AMS Pilot Spinning Plant was performed by the Stoneville and Mesilla Park Laboratories to establish the merits of vapor-phase and liquid-phase cotton moisture restoration methods as aids in retaining or restoring fiber properties in jeopardy because of low moisture content before cleaning and ginning. Both of these methods are adaptations, developed on data from Stoneville tests carried on about 12 years ago. Spinning data from the Pilot Spinning Plant is not yet available, but on the basis of fiber arrays from each of 21 test lots in the Stoneville test, short fiber content increased as the degree of drying increased, and both methods of moisture restoration showed decreases in short fiber content compared to the lots dried and not receiving moisture restoration.

Seed Cotton Cleaning. A machine for the removal of grass from seed cotton was developed and tested at Stoneville. It was found to be effective and to have no measurable adverse effect on the fiber and spinning quality of the lint. Tests at Stoneville and Clemson show that a recommended amount of seed cotton cleaning followed by double lint cleaning is also very effective in the removal of grass. Therefore, the design of the grass removal machine is not being refined and it is not being recommended to the industry.

Tests at Clemson using a three-cylinder large drum cleaner show that leaf trash is much more readily removed from hand-harvested cottons than from machine-picked cotton. For this reason when hand- and machine-picked cotton are harvested with the same foreign matter content, the hand-picked cottons will yield the highest grade lint.

Tests at Mesilla Park show that passing machine-picked cotton through a separator and drier as many as seven times at relatively low temperatures has been found to be effective in the removal of leaf trash which is shaken free of the cotton in the drier and exhausted with the drying air. The treatment did not adversely affect any of the measurable fiber properties.

Encouraging results are being obtained at Stoneville on an airline cleaner which has no moving parts.

A settling type green boll trap was designed, constructed, and tested on stripped cotton at Chickasha, Oklahoma. The unit worked quite satisfactorily at a rate of three bales per hour but at higher rates, equivalent to commercial gin operation, the efficiency of this size unit was too low to be acceptable.

Harvesting-ginning studies at Chickasha in cooperation with the Oklahoma Experiment Station using stripped cotton showed that boll breaking at the gin prior to drying will (1) decrease the effectiveness of gin bur machines; (2) lower leaf and mote content in the seed cotton but not sufficiently to be reflected in price; (3) substantially increase gin turnout; (4) increase fiber fineness and nep count; and (5) not affect fiber strength, length, and length distribution.

Cleaning equipment on the stripper will usually increase gin turnout by leaving some foreign matter in the field and this in effect reduces gin costs. However, cleaning cotton within the stripper is not economically feasible because ginning costs per bale are not decreased sufficiently to justify the increased stripper cost.

Two types of "hard lock" separators, an auger type and a drum-type, were constructed at Clemson for testing. The auger type appeared to be slightly more effective in bad lock removal and the principle will be used as a basis for further research to develop a means for removing this inferior cotton during ginning.

Conveying. A small-diameter pipe, medium-pressure, trash handling system developed at Mesilla Park was subjected to field tests in a commercial gin. The system is capable of handling 12,000 pounds of trash per hour and the tests show that it is commercially feasible. The tests also show that this type system results in a large saving in power over conventional methods and the small volume of air required for moving the material can be cleaned easier than the large volumes required by conventional methods.

Gin Stands. A new flight-bar roller gin developed at Mesilla Park was installed and operated at a commercial roller gin for one month during the 1961-62 ginning season. The gin was operated by the commercial gin crew mechanics and operation techniques required were studied by research engineers. The Laboratory gin was replaced by the first known commercial model experimental flight-bar gin in early December. The unit proved to be successful and the manufacturer is placing 16 improved models of their flight-bar gin in the field for ginning during the 1962-63 season.

The instrumentation was completed on a standard-type 60-inch roller gin to determine accurate settings for (1) ginning roll to fixed knife pressures; (2) fixed knife operating temperatures; and (3) speeds of rotational members. Operating without cotton at a ginning roll speed of 110 r.p.m. and with roll to fixed knife pressure in the range of 24 to 35 p.s.i., the knife came to an equilibrium temperature of 165° F. Optimum ginning pressures have not yet been established but are predicted to be substantially above 35 p.s.i.

Tests at Stoneville indicate that the saw gin stand, with the exception of nep formation, reduces fiber quality no more than lint cleaners and no more than a moderate seed cotton cleaning setup. Tests using different varieties show that cottons having long low-strength fibers are not subject to more fiber breakage during ginning than short staple high-strength varieties and that during ginning neps increased directly in proportion to length and fineness. Except for nep formation, hand ginning produces samples more nearly representing the fiber qualities of the cotton as received at the gin than does roller ginning. Increasing the number of teeth on a 12-inch diameter gin saw above 264 reduces the capacity, increases neps, and does not improve the moting efficiency.

A free turning core in the gin stand seedroll box was tested at Stoneville from a capacity standpoint. This was similar to devices tested by the Laboratory during the development of the agitator for increasing gin stand capacity. Two series of tests were conducted involving specific locations with respect to the gin saw. These tests showed this core to be practically worthless.

Initial tests of a new gin stand design did not prove to be successful.

Gin Performance and Cotton Quality. Studies of the power requirements and ginning efficiency at Stoneville have pointed up opportunities for increasing efficiency and reducing power requirements. As a result of this work two devices to provide a means for getting cotton to the gin stands rapidly to reduce the delay between bales and an arrangement to eliminate the overflow have been planned and patents applied for.

A similar study is underway in California and on the High Plains by the Mesilla Park Laboratory.

This work at both Laboratories is being carried out in cooperation with the Economics Research Service.

Measures of quality. A method for quantitatively determining the amount of seed coat fragments in a lint sample is under development at the Stoneville and Mesilla Park Laboratories. The Stoneville Laboratory is taking the lead in Task Group work for the adoption of the test by American Society for Testing Materials.

A fiber array procedure was developed at Stoneville which required only two-thirds of the time required for a conventional array. The method is being used in evaluation work at the Laboratory. Also, a seed cotton sorter was tested to determine if it could be used to detect differences in seed cotton caused by various processes. This device was not successful.

At Mesilla Park a fiber-sorter of unique design is being tested. Bench model tests appear promising.

Studies at Mesilla Park show that resilience of fibers is negatively correlated with moisture content. Also, moisture, absorption varies with fineness and maturity. Using this information, an equation for predicting lint moisture content of upland cotton was developed based on two rapid measurements--micronaire and resilience.

Maturity and fineness can be determined from the micronaire reading when using a table developed by the Mesilla Park Laboratory.

Using 472 samples from seven varieties of cotton, comparisons were made with conventional Causticaire measurements. The new method was found to be statistically significant at the 99 percent confidence level.

Studies at Mesilla Park show that with American-Egyptian and Upland varieties and strains, low strength of attachment of fiber and seed is usually associated with higher ginning capacity, fewer neps, less linters and lower percentage of short fibers.

Tests at Stoneville of the fiber-seed separation force and breaking force for more than 400 separate fibers showed that for fibers longer than one inch on the same seed a wide range of separation and breaking strength exists--typically, from 1 to 3.7 grams separation force and from 1.3 to 8.4 grams breaking force.

For four cotton varieties studied the mean fiber-seed separation force was 52 to 56 percent of the breaking force for the same fibers. On the average, about 13 percent of the fibers broke before being pulled from the seed. These studies show that regardless of the method used to remove the lint from the seed, there will be some fiber breakage.

Effects of variety and cultural and harvesting practices on lint quality. A cooperative study between the Mesilla Park Laboratory and the Cotton Mechanization Project showed that an elaborate ginning setup on cotton which was harvested by a once-over stripping operation resulted in highest net returns to the producer.

A test to compare the cleaning effectiveness of smooth leaf cotton as compared with a hairy variety was carried out at Stoneville in cooperation with the Delta Branch Experiment Station. There was no statistical difference between varieties as to the percentage of trash removed by the gin. The smooth leaf cotton comes from the field cleaner and gives cleaner lint. When this cleaner smooth-leaf cotton comes into widespread use it is possible that less gin cleaning machinery will be needed to yield relatively high grades.

At Mesilla Park cooperative studies with the Experiment Station on four planting dates and two harvesting periods showed no significant differences in fiber qualities between the planting dates. However, fiber properties were significantly better for the early-season harvesting.

Tests at Stoneville in cooperation with the Cotton Mechanization Project showed that there was no difference between the defoliation treatments when the bolls were 60 percent open and when the bolls were 75 percent open, from the standpoint of gin performance. However, from agronomic and economic viewpoints, based on grade alone, early defoliation with two harvestings is better than late defoliation and one harvesting.

Defoliation tests at Mesilla Park in cooperation with the New Mexico Experiment Station showed that defoliation improved the grade of machine-picked cotton an insignificant amount when an elaborate gin setup was used.

A study at Stoneville in cooperation with the Cotton Mechanization Project showed that picker spindle lubricating oils seriously affected the spinning performance of cotton. The cotton has very poor carding and running qualities in the mill and also tends to have higher manufacturing waste and nep count and lower yarn strength and appearance.

Tests at Chickasha in cooperation with the Experiment Station showed that an alcohol or silicone compound as a picker spindle moistening and cleaning agent showed no significant effects on fiber properties by laboratory analysis.

At Stoneville, in cooperation with the Delta Branch Experiment Station, eight commercial varieties were compared from the standpoint of mechanical harvesting and gin cleaning in terms of foreign matter content and lint grade. Delta Pine Smooth-leaf, Stoneville Smooth-leaf, and a USDA smooth-leaf strain averaged highest in grade for the varieties tested. A study of six varieties of widely varying stalk and boll characteristics showed no differences from the standpoint of picker efficiency.

Tests of lay-by herbicides at Stoneville in cooperation with the Delta Branch Experiment Station showed that when elaborate gin cleaning machinery was used there was no difference between the cottons harvested from a grassy field as opposed to cotton harvested from a field kept free of grass by a lay-by chemical. The gin machinery removed grass from the cotton thereby nullifying the effect of the lay-by chemical.

Cooperative tests at Stoneville in cooperation with the Cotton Mechanization Project in gleaning cotton from the ground showed that cotton could be picked up from the ground quite successfully prior to rains. The ginned lint from comparatively early-season cotton picked up prior to rain brought a price of 33½ cents per pound whereas late season cotton left on the ground a week following rains was valued at 29 to 30½ cents per pound.

Lint Cleaning. The Stoneville and Mesilla Park Laboratories in cooperation with the National Cotton Council, Agricultural Marketing Service, and Economics Research Service, conducted a multiple lint cleaning test at six gins across the Cotton Belt during the 1961-62 season. Results of the study show (1) grade is improved by lint cleaning; (2) staple may be slightly affected in some cases; (3) bale weights are reduced by each subsequent state of lint cleaning; (4) lint cleaning will pay on grades of SLM and below even when differences are very narrow; and (5) costs of providing lint cleaner service can amount to \$1.00 per bale for each stage of lint cleaning and this must be borne by the ginner or grower.

This confirms a test made at two gins by the Stoneville Laboratory in cooperation with the Economics Research Service during the 1960-61 season. This study also showed that machine-picked cotton in the Mississippi Valley area should be processed through two saw cylinder lint cleaners preceded by some 12 cylinders of seed cotton cleaning for the farmer to receive optimum returns for his cotton.

At Stoneville tests on various numbers of grid bars show that the number of grid bars and their settings has an effect on fiber length distribution.

Lint foreign matter determination. During the year two models of a laboratory fiber cleaner were designed and tested at the Stoneville Laboratory. The purpose of the machine is (1) to blend a sample; (2) measure foreign matter content; and (3) prepare a sliver for subsequent fiber tests. Test results using a 25-gram sample seem to be favorable for foreign matter determinations when compared to Shirley Analyzer total waste percentages.

Cottonseed Drying, Cleaning and Storage. A pneumatic, counterflow cleaner was developed at Stoneville for the removal of fine trash from cottonseed. On lots of seed which ranged 2.2 down to 0.28 percent foreign matter, the cleaner was found to be effective in the removal of some 50 percent of the material.

Cooperative cleaning tests carried out in cooperation with the Small Seed Harvesting and Processing Investigations at Corvallis, Oregon, did not provide any promising leads for the cleaning of cottonseed.

Gin Waste Disposal. Studies at Stoneville in cooperation with the Delta Branch Experiment Station showed that the application of gin trash to the soil did not result in increased cotton yield.

The application of gin trash to the soil has been found to be beneficial in the western part of the Belt so the Mesilla Park Laboratory in cooperation with the Bureau of Plant Quarantine carried out a series of studies on the mechanical treatment of gin trash which resulted in the changes of Federal Quarantine regulations to allow gin trash to be returned to the soil and for the interstate movement of lint cleaner waste.

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AREA 7, STRUCTURES FOR CROP AND MACHINERY STORAGE AND PLANT GROWTH

Problem. The magnitude of the crop and machinery storage problem is evidenced by the vast quantities of materials handled and stored on the farm. Annually on the farm: (1) Five billion bushels of corn, wheat, and other grains are harvested and stored, of which nearly 1 billion is carried over from the preceding year; (2) 185 million tons of hay and silage are processed and stored; (3) nearly 3 million bushels of apples and pears and 13.5 million hundred-weight of potatoes and sweet potatoes are held for home consumption; (4) other large quantities of fruits and vegetables are held for temporary storage pending marketing; and (5) large amounts of fertilizers and feeds are purchased and held in storage pending use. An aggregate total of more than seven million tractors, combines, corn pickers and other complicated farm machines would retain their efficiency longer and operate more reliably if stored under shelter and tuned up in farm shops.

Relatively little research on farm storage has been done in recent years by USDA, the State Experiment Stations or industry--even though there have been many new developments that affect storage and handling problems. Among these new developments may be mentioned:

Changes in harvesting methods such as picker-shelling of high moisture corn, wafering of forage, combine harvesting of potatoes, and mechanical harvesting of apples and other fruits and vegetables.

Need for integrating feed storage into complete feeding systems; for example, large diameter silos with feed bunks, paved feeding area, and a conveyor system.

Development of electrically operated and controlled mixing and metering systems, and so on.

Increase in number of rural non-farm families outside of villages that raise some of their own fruits and vegetables.

The cold war situation and potential fallout hazard that emphasizes value of locally available feed and food supplies, and introduces requirements for new designs and arrangements for the storage and operating facilities.

There is also urgent need to develop engineering design criteria for constructing and equipping plant growth chambers that will reliably provide and maintain desired thermal, lighting, and other environments over a wide range of experimental conditions. Recent experience of plant and other scientists concerned with use of plant growth chambers indicates a general inability to closely maintain desired environmental conditions and a lack of means for measuring conditions maintained in these units. Design criteria for automatically maintaining scheduled environments are needed also for greenhouses and other production type plant growth structures.

USDA PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for storage and plant growth structures.

Crop storage structures (silo) research is cooperative with AH, ARS, and with Cooperative Regional Research Project NE-13, "Determination of the Basic Job Requirement of Machinery for Harvesting and Storage of Grass Silage", at Beltsville, Md., and with the Agricultural Experiment Stations at Athens, Ga., East Lansing, Mich., and Ames, Iowa. Typical plans for storage structures and related equipment are developed at Beltsville in cooperation with the regional committees representing all State Experiment Stations and Extension Services.

Plant growth structures (environmental chambers and greenhouses) research at Beltsville, Md., is cooperative with CR Division, ARS.

The Federal effort in this Research Area totals 4.9 professional man-years. Of this number 3.6 is devoted to crop storages; 1.0 to plant growth structures; and 0.3 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 11.7 professional man-years divided among subheadings as follows: Crop storages - forage, 5.2; deciduous fruit, 0.7; grain, 2.4; potato and sweet potato, 1.5; tobacco, 0.6; plant growth structures, 1.0; machinery storage and shops - 0.3. Part of this work was on off-farm storage.

Forage storage studies, including silage, that are in progress in all four regions are concerned with developing satisfactory and economical structures and with improved designs, equipment and methods for reducing the amount of labor required for moving forage into and out of storage. Structures with provision for conditioning equipment and self-feeding features for long and short cut forages were designed, tested, and evaluated. These studies contribute to Cooperative Regional Projects NE-13 and NC-48, "Development of Materials Handling Systems for North Central Farms"

Deciduous fruit storage research was on design of improved controlled-atmosphere storage and development of plans for improving existing storage. Grain storage research involved basic and applied work on design factors, equipment, requirements, and operating procedures for maintaining quality of grain through the use of conditioned air.

Potato storage investigations sought improved construction and operation of storages to preserve various varieties of potatoes for specific uses, and involved study of the effect of preharvest, harvest time, and storage condition on successful operation of the storage.

Tobacco building research involved improvement of existing types of structures, including installation of modern handling equipment.

Plant growth structures research dealt with use and testing of plastic films for greenhouses and with the integration of recent developments in lighting, heating and temperature and humidity control equipment into structures to provide complete environmental control.

A small amount of other research dealt with machine storage sheds and shops, including an attempt to devise standard interchangeable building components.

Industry Research. A recent survey by the National Silo Association found more than 60 silo companies reporting engineering research projects. Most of these are aimed at keeping their product designs abreast of the requirements of new silage materials and production methods. Changes are occurring so rapidly that much of the design data previously developed by State and Federal research is becoming obsolete. Estimated annual expenditures are equivalent to approximately 10 professional man-years. No other research by industry on crop storage or plant growth chambers was reported. Probably less than 10 percent of the general research effort by industry on materials would apply to farm crop and machinery structures.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Crop Storage Structures. At Beltsville, Md., the dry matter capacity of a bunker silo was 5 tons greater when filled with wilted alfalfa silage (97 tons at 68 percent--wet basis--moisture) than when it was filled with direct cut orchard grass (135 tons at 81 percent moisture) in the previous year. The benefit of this greater dry matter capacity was enhanced by the reduced weight that must be handled from the field and by a decrease in odor and seepage. During filling with wilted alfalfa, average horizontal wall pressures increased with increasing depth of silage to about 92 pounds per square foot when the depth reached 4 feet. Pressures remained about the same with greater depths up to 7 feet--the maximum depth measured. These values were from 40 to 70 percent of pressures measured when the silo was filled with direct-cut forage in former years. Vertical loads on the wall increased uniformly to 80 pounds per square foot of wall surface area at 7 foot depth--about the same as measured in former tests. This test indicated that, although the lower moisture content of wilted forage tends to reduce horizontal pressures, it has little effect on vertical wall loads in horizontal silos. Additional trials are needed to confirm this assumption and to determine the effect of filling with different crops.

Temperatures were measured in the center and at the top of the section of silage that was placed in the silo on each of 3 days. The temperatures at the center of the first of the three sections peaked at 110° F., that of the second, 100° F., and of the third, 114° F., respectively, 2, 9, and 2 days after filling, showing that air exclusion was satisfactory. The greater length of time required for the temperature of the second day's fill to peak could have been influenced by the one-day interruption in filling and in the higher moisture content of the silage. The approximate moisture of the material ensiled the first day was 65 percent--wet basis, that ensiled the second, 75 percent, and that ensiled the third day, 55 percent. A seal of 4-mil black polyethylene along each side, and neoprene-coated nylon cover--weighted with sawdust--over the top protected the shoulders of the silage and eliminated spoilage except at breaks in the film at the silage surface.

In a third filling, this same bunker silo was filled with wilted material of 53 percent--wet basis--moisture content to compare silo capacity at this moisture content with that at two previously studied moisture contents, 68 and 81 percent. Results conformed with those of the previous years in that the dry matter capacity of the silo was greatly increased when ensiling a low moisture material.

At the 53, 68, and 81 percent moisture levels, the respective capacities were 15.4, 11.3, and 7.7 pounds of dry matter per cubic foot of silage. Ninety percent of the ensiled dry matter was recovered as feed from material ensiled at 53 percent moisture content and 87 percent of the dry matter was recovered from material ensiled at 68 percent moisture content. Losses due to spoilage were reduced when plastic film placed along the walls of the silo was folded over the silage surface before applying the top cover, as compared to merely placing the top cover to meet the side wall without a fold. This method would become more important in silos filled with heavily wilted material. Temperatures of the 53 percent material peaked at 105° F. two weeks after filling and then cooled and followed ambient temperatures. These peak temperatures showed satisfactory air exclusion and were only from 3° to 5° above peak temperatures found in tower silos filled with similar heavily wilted material.

The average horizontal pressures with each 6 inch interval of depth in this bunker silo increased uniformly to about 125 lb./sq. ft. at a depth of 4 feet and thereafter decreased to about 100 pounds with an 8-foot depth. The maximum pressure measured was 150 pounds per square foot. Average vertical loads on the walls during filling were negative to a depth of 4 feet due to re-expansion of the packed material, and increased to about 50 lb./sq. ft. of wall area at a depth of 8 feet. Within the first five days of settling, all vertical pressures became positive and increased at a rather uniform rate from 0 to 40 lb./sq. ft. at the 7'-9" settled depth. Similar results were obtained in Georgia when silos were filled with Bermuda or Rescue grass or fescue and sericea lespedeza.

At Athens, Ga., three horizontal silos were filled experimentally in each of the two years. Each silo was covered with 6-mil black polyethylene film each year. The first year, two covers were weighted with sawdust and the third unweighted but held in place by earth placed around the edges of the plastic. The second year, all three were weighted with sawdust and the third was weighted with tires in addition to the sawdust. All covers were effective in reducing spoilage and returned more than their investment. This has been a consistent finding. Weighted covers were more effective than unweighted.

Self-feeding from all three horizontal silos was continued with satisfactory results. The silage was self-fed to a beef cow herd, a beef steer herd, and a dairy herd. A total of 6 man-hours per week were required to service the silos for self-feeding as compared to 56 man-hours per week formerly required when dry hay was fed.

In preliminary tests in Michigan, mature corn silage (of 67.7 percent average moisture content) exerted horizontal pressures amounting to approximately 10 pounds per square foot per foot of depth and vertical loads of about 2 pounds per square foot of wall area per foot of depth in 20- and 30-foot diameter silos 60 feet high. Horizontal pressures in 30-foot diameter silos filled with corn of only 63 percent moisture content were about 5 lb./sq. ft. per foot of depth, and vertical pressures amounted to only 2 lb./sq. ft. of wall area per foot of depth. This may indicate that low moisture corn silage acts less like a semi-fluid and that a large percentage of the load is carried by the silo floor. The pressures measured in these tests should not be used for design purposes until confirmed by additional tests, including tests with higher moisture materials. The pressures appear to be exceptionally low, perhaps due to uneven distribution of low- and high-moisture materials. For example in the 30-foot silo with 63 percent moisture corn, the material in the lower part of the silo was drier than the average of the entire contents of the silo and much drier than typical silage.

Two tile tower silos at Beltsville were filled with heavily wilted first-cutting alfalfa in 1960 to evaluate them as a means of storing and preserving this material and to determine what special precautions or filling methods are necessary in their use. Tar paper was as effective as vinyl door gaskets for covering the doors. A single plug of high-moisture silage placed after 3 days of filling was as effective in eliminating visible evidence of the presence of oxygen as were plugs placed at the end of each day during filling.

One tower silo was lined with vertical strips of a special aluminum sheet. The sheets were cemented to the walls and to each other with a neoprene base glue. A few blind rivets were placed in each joint for mechanical bond. Time will be required to determine the efficiency and economy of this method of rehabilitating old silos.

Basic work in cooperation with the Georgia College Experiment Station was initiated during 1962 using glass jars as miniature silos in an effort to determine the effects of various treatments on Bermuda grass silage quality. A total of 588 jars were filled with Coastal Bermuda grass and sealed to varying degrees of air-tightness. The other treatments used were moisture content, density, kind and amount of preservative, exposure before sealing, stage of maturity and air infiltration. Analysis of this work has not been completed.

A change in emphasis is anticipated with the completion of analysis of results obtained from the full scale silo work at Watkinsville, Ga.

Preliminary tests were made at Beltsville on wafers made by a field wafering machine and stored as silage and in dry storage. Results indicate that aeration of wafers in dry storage can be accomplished with low capacity fans. The resistance of clean dry wafers to air flow is comparatively low; the inclusion of trash, the methods of handling, and the moisture content of the wafers can greatly increase the resistance.

At Ames, Iowa, samples of high moisture corn from sealed storage having various degrees of spoilage were tested by the Animal Husbandry Division for protein nutritive value. Little difference was observed between "good" and "poor" samples of wet stored grain in rat feeding tests. Four small silos (6'x15') were set up for measuring the rate of leakage of air, and measuring the effect of controlled air leakage on the quality of the stored corn. These tests will give better data on the relation between air penetration and quality.

Six typical plans for storage structures or structures for storage combined with some other activity developed at Beltsville, for the Cooperative Farm Building Plan Exchange include a pole type corn crib (35 bushel per foot of length), a hay shed (2 1/2 tons baled hay per foot of length), a potato storage (60,000 cwt), a drying and storage shed (25' x 45'), a small storm and storage cellar, and a small storage and fallout shelter.

Plant Growth Structures. Research to develop engineering design criteria for plant growth chambers was initiated at Beltsville, Md., in 1961. The study includes installation of instruments and analyzing records of operation of growth chambers under actual use to determine future specifications and research needs. Consultation and service for scientists who are using or plan to use plant growth chambers has also been provided for scientists located at Beltsville, as well as others in various parts of the United States. A trip was made to Bogota, Colombia, to help the Rockefeller Foundation set up and check out a group of plant growth chambers.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Crop Storage Studies

Boyd, J. S., Yu, W. W., and McCalmont, J. R. 1960. Silo pressures in tower silos from two years' tests. Presented at Winter Meeting, ASAE, Memphis, Tennessee, December 4-7.

Gordon, C. H., Derbyshire, J. C., Jacobson, W. C., Kane, E. A., Melin, C. G., and McCalmont, J. R. 1961. Comparisons of unsealed and plastic sealed silages for preservation, efficiency and feeding value. Jour. of Dairy Sci. V. XLIV, No. 6, June.

Gordon, C. H., Derbyshire, J. C., McCalmont, J. R., and Moore, L. A. 1961. Making low-moisture silage in regular tower silos. ARS 44-101, September.

Langston, C. W., Gordon, C. H., Jacobson, W. C., Melin, C. G., Moore, L. A., and McCalmont, J. R. 1962. Chemical and bacteriological changes in grass silage during the early stages of fermentation. I. Chemical changes. Jour. of Dairy Sci., March.

Open hay storage building. (Exchange Plan No. 5879). USDA Misc. Pub. No. 834, January 1961.

A drying and storage shed. (Exchange Plan No. 5869). USDA Misc. Pub. No. 835, March 1961.

Pole corn crib. (Exchange Plan No. 5878). USDA Misc. Pub. No. 839, April 1961.

Plant Growth Structures

Bailey, William A. 1960. Fan and pad system of cooling greenhouses and other farm buildings. Presented at Summer Meeting, ASAE, Amherst, Massachusetts, August 22-24.

Cathey, H. M., Bailey, W. A., and Borthwick, H. A. 1961. Cyclic Lighting--To reduce cost of timing chrysanthemum flowering. The Florists' Review, September 21.

AREA 8, RURAL DWELLINGS

Problem. Incomplete reports from the 1960 Census of Housing indicate that although about 500,000 new farmhouses were built between 1950 and 1960 rural housing as a whole continues to be older than and inferior to urban housing in condition and value of buildings and in availability of plumbing, heating, and labor-saving equipment. Projections of incomplete data indicate that the percentage of farmhouses with flush toilets increased from 27 percent to between 50 and 60 percent between 1950 and 1960, and that the percentage without piped water supply was reduced from 55 percent to about 20 percent in the same period. However, the improvement in these percentages was due partly to change in the Census definition of a farm which removed from the "farmhouse" classification of the Census some 2 million houses on small acreages or on land that had been consolidated into larger holdings. Many of these homes must now be included in the rural "non-farm" category. But whether classified as "farm" or "non-farm" large numbers of houses outside of cities and towns remain without the conveniences and comfort features of typical urban homes.

Housing costs are still a major obstacle for farm families that wish to make improvements for themselves or to furnish better housing to attract and hold qualified and reliable tenants or full-time or migratory workers. Costs are also a problem for the rural non-farm family. Continuing research is needed on ways to reduce costs through better use of space and improved application of old and new materials. There is need for more simple, really low-cost designs that provide only the minimum essentials of good housing; and the "shell house" should be studied for further improvement of its first stage and to make completion easier.

On the other hand, the stepped-up Farmers Home Administration program of rural housing loans needs research support to provide designs that will meet modern housing standards at moderate cost and be sound and desirable security for 30-year government loans. The design and equipment of houses for improved control of temperature and moisture, and economy of operation and maintenance also need further research.

With the rapid increase of the non-farm population in rural areas outside of villages, including many elderly and retired people, more attention should be given to their housing. People who have vegetable gardens and garden equipment to store, and who live on small acreages, drawing water from wells and using septic tank sewage disposal systems, have housing problems very like those of farmers, and the housing abilities of the Department could be very useful to them. Engineering research and design of equipment for the elderly is also needed.

In view of the continuing and expanding "cold war", consideration should be given to types of both farm and non-farm houses that would provide shelter from fallout if an emergency should develop. Basements could provide fallout shelter at small additional cost for families that do not have to care for livestock. Development of types of houses having the basement as an attractive area for full-time use is a challenging problem and would be a valuable achievement. On livestock farms, the family fallout shelter probably should be in the main livestock building.

USDA PROGRAM

The U. S. Department of Agriculture is conducting a continuing program of housing research involving engineers and architects.

Five experimental houses at the Agricultural Research Center are under continuing evaluation of design, temperature control features and occupant reaction, in cooperation with Clothing and Housing Research Division, ARS. Construction methods and materials and temperature control are studied at Beltsville and at Athens in cooperation with the University of Georgia. Architectural design and preparation of farmhouse plans for the Cooperative Farm Building Plan Exchange and related publications are carried on at Beltsville in cooperation with Clothing and Housing Research Division, ARS, and the Federal Extension Service. The State Agricultural Colleges cooperate through Regional Committees in establishing housing requirements and making the plans available to the public. Farmers Home Administration consults on requirements and makes plans available to its clients.

Federal work in this Research Area totaled 5.8 professional man-years in 1961. Of this number, 3.0 were devoted to design criteria for comfort, health and safety; 0.4 to studies of materials and construction; 0.3 to systems for environmental control; 1.7 to development and preparation of improved farmhouse designs; and 0.4 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Stations in 1961 reported 2.2 professional man-years on dwellings, including an estimated 0.6 on equipment for environmental control (Area 13). These studies were part of Cooperative Regional Projects NC-9, "Utilization of Materials to Meet Housing Needs", and S-8, "Functional Requirements for Southern Rural Homes". Part of the work on materials, construction and plan development reported in Research Area 10 applies to dwellings.

Industry did not report specific research on farm housing, but manufacturers of building materials and of mechanical and electrical equipment carry on development of new products, many of which will prove valuable on the farm. An estimated 5 professional man years per year would apply to farmhouses.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

In cooperation with Clothing and Housing Division, ARS, a study was conducted in five states having active Farmers Home Administration programs to determine the importance of various field construction problems and the need for plans and planning aids. This survey showed the need for better winter heating and summer cooling in existing farmhouses, for reduction of building costs, and for better ways of getting building information to farm people. Work on these problems is being started at Athens and Beltsville. Since farmhouses are currently being built at the rate of only about 12 houses per 1,000 farms per year, it is evident that improvement of existing houses must be relied upon if an appreciable portion of farm families are to benefit within the near future.

Preliminary analysis of data taken in four of the experimental houses at Beltsville in 1961 indicates that greater air temperature stratification occurred in the houses with unheated concrete slab floors and insulated ceilings in combination with no cold air return ducts. A wooden floor above crawl space with cold air return ducts and insulated walls and ceiling provided the least stratification. House D, with warm air flues in the perimeter of the concrete slab and an insulated ceiling, performed well although the brick walls were not insulated. Temperature drop through walls with construction that permitted high infiltration into the insulated stud space indicated a loss in insulation efficiency.

A bedroom addition, including several experimental features, has been designed for House D. This should provide information on the livability and environmental performance of certain building materials and on a heat distribution system using the space between plywood floor and concrete slab as a plenum.

An examination of a four-inch bituminized fiber sewer pipe laid seven years ago to a depth of 39 inches in heavy clay soil near the foundation wall of House E at Beltsville revealed that the pipe had flattened only 1/8 inch thus providing very satisfactory service.

At Athens an automatic, data-logging weather station has been developed to record weather data needed in housing environment studies. It is currently collecting data on the following nine weather factors: Dry bulb temperature, dewpoint temperature, total hemispherical radiation, wind velocity, wind direction, black globe temperature, precipitation, soil temperature and soil moisture. Transducers to measure net hemispherical radiation, evaporation and barometric pressure will be added. The station logs one complete set of data each half-hour in the form of a punched IBM card which can be used for direct computer analysis and columnar print-out of data. This should save a great deal of time in analyzing results of the housing studies. Manuscript for a bulletin describing the weather station, circuitry for all sensing elements, and digitizing and punch card equipment hook-ups, is being prepared as similar equipment would be useful for many other purposes.

Thirteen farmhouse plans released between April 1, 1960 and March 31, 1962, were designed for a wide range of economic needs, and geographic adaptability to meet specific requests of the Regional Plan Exchange Committees. The plans include two for minimum houses without bedrooms, one for a relatively large one-bedroom farmhouse, three for two-bedroom farmhouses (two with basement), five for three-bedroom farmhouses (one with basement), and two for four-bedroom farmhouses (one with basement). Liberal space allowances are designed into two of the three-bedroom plans, and one of the four-bedroom plans. The other plans are designed for modest cost of erection at the sacrifice of space.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Design Criteria

Biggs, Archie A., and Courtless, Joan. 1961. Evaluation of construction, materials, and livability of five expansible farmhouses. USDA ARS Series 42-45.

Thompson, Harold J., and Simons, Joseph W. 1961. Some effects of construction and climatic factors on heating five expansible farmhouses. USDA ARS Series 42-46.

Home sewing areas. 1961. Supplement A to Southern Cooperative Series Bulletin No. 58.

Farmhouse Plan Leaflets

One bedroom farmhouse. (Exchange Plan No. 7146). USDA Misc. Pub. No. 826, August 1960.

Two bedroom farmhouse with Beltsville kitchen. (Exchange Plan No. 7149). USDA Misc. Pub. No. 827, August 1960.

Two bedroom farmhouse - slab-on-grade. (Exchange Plan No. 7158). USDA Misc. Pub. No. 828, August 1960.

Three bedroom farmhouse with Beltsville kitchen. (Exchange Plan No. 7152). USDA Misc. Pub. No. 829, October 1960.

Two bedroom farmhouse with basement. (Exchange Plan No. 7157). USDA Misc. Pub. No. 830, October 1960.

Three bedroom farmhouse with attached two-car garage. (Exchange Plan No. 7132). USDA Misc. Pub. No. 842, March 1961.

AREA 9, LIVESTOCK ENGINEERING (Except Electrical)

Problem. The American farmer has about \$14 billion invested in service buildings and related structural equipment, over half of it for livestock facilities. Maintenance and new construction amount to another \$1.2 billion annually, again mostly for livestock facilities.

Economic conditions are forcing changes in the pattern of livestock production. Producers are trending toward fewer, larger and more specialized enterprises and toward "confinement" types of facilities in their efforts to reduce production costs and improve product quality. These trends are demanding more basic knowledge on the effects of environment on the health, growth, production and fertility of livestock; on structures and related equipment for maintaining optimum environments; and on methods, structures and equipment for more efficient handling and feeding. The continuing threat of nuclear warfare demands consideration of types of buildings that could provide protection from fallout for livestock and their feeds, and provide facilities for operation during periods of emergency.

Much more needs to be learned in the laboratory on the relationships between livestock environment and disease transmission, feed conversion rates, growth and production in order to determine optimum environments. Structures and equipment for economically providing these optimum environments under practical conditions need to be developed and field tested. Closely associated with the environment are flies and other insects, as well as parasites and diseases, that sap the vitality of animals and reduce their productivity. Pesticide residues in animal products are causing much concern.

Labor also is an important element in overall production costs, and if only family labor is available, the labor requirement limits the size of enterprise. How to adapt existing buildings and other facilities for more efficient production, as herds and flocks are increased in size, or as farms are consolidated, is a major problem area. Cost of replacement or major improvement of existing buildings that are not suited to modern production methods are serious obstacles. Principles, examples and techniques for planning more efficient operations are needed both by farmers doing their own engineering and by those on whom farmers depend for advice.

Many types of structural and handling equipment such as feed bunks, self-feeding silos, and feeding floors, are important to a livestock production enterprise. Adaptations and improvements to keep design of such equipment abreast of current production practices and buildings are essential to the producer.

USDA PROGRAM

This is a continuing program involving engineers and architects conducting basic laboratory investigations, application of laboratory results to a production basis, and development of typical plans for livestock structures. The work is in cooperation with the AH, ADP and ENT Divisions of ARS, USDA, and State Agricultural Experiment Stations, and contributes to Cooperative Regional Projects NC-23, "Farm Structures to Meet Environmental Requirements of Dairy Cattle, Swine, and Poultry", S-49, "Genetic Methods of Improving Dairy Cattle for the South", and NE-8, "Essentials of Poultry Housing for the Northeast". Plan development work is cooperative with all the State Agricultural Experiment Stations and Extension Services.

Dairy cattle environmental and bio-engineering studies are conducted in a climatic laboratory at Columbia, Mo., in cooperation with the Dairy Husbandry and Agricultural Engineering Departments of the Missouri Station. AH, ARS, serves in an advisory capacity. Field studies in a hot humid region are conducted at Tifton, Ga., with the Georgia Coastal Plain Experiment Station and AH, ARS, cooperating. The influences of building arrangement, equipment, and chore routines on the amount and drudgery of dairy chores and means of improving these factors are conducted in cooperation with the California, Maryland, and Minnesota Agricultural Experiment Stations. Typical plans for dairy structures are developed at Beltsville as part of the Cooperative Farm Building Plan Exchange.

Beef cattle structures and equipment research for hot, dry climates is conducted in cooperation with the California Agricultural Experiment Station at the Imperial Valley Field Station, El Centro. Related studies in a warm humid climate are in cooperation with the Georgia Agricultural Experiment Station at Tifton, with AH, ARS advice. Typical plans for beef structures are developed at Beltsville.

Swine structures and equipment research is in cooperation with the California Agricultural Experiment Station. Methods of modifying the thermal environment are being investigated in field studies at Davis and at the Imperial Valley Station, El Centro. With the additional cooperation of a hog producer, the influence of building type and arrangement on efficiency of animal growth is studied on a production scale. Studies of the effects of floor space per animal on growth and feed consumption have been concluded. Typical plans for swine structures are developed at Beltsville.

Sheep shelters have received limited study in cooperation with the California Agricultural Experiment Station, and plans for sheep buildings and equipment are prepared at Beltsville.

Poultry house environmental design criteria are investigated in controlled-temperature laboratory studies at Beltsville, Md., in cooperation with AH, ARS. Field studies on relation of housing structures to poultry disease are conducted in Mississippi in cooperation with the State Station and AH, ARS. Environmental influences on health and housing are to be investigated in new laboratories at Athens, Ga. and State College, Miss., in cooperation with AH and ADP, ARS, and the respective State Agricultural Experiment Stations. At St. Paul, Minn., a study of the role of environment in the prevention and control of chronic respiratory disease in turkeys is under way in cooperation with the Minnesota Station. Typical plans for poultry structures are developed at Beltsville.

Reduction of pesticide residues in animal products, with beef cattle receiving major attention, is studied at Kerrville, Texas, in cooperation with ENT and ADP, ARS, and the Texas Agricultural Experiment Station.

Federal research effort in this area totals 11.3 professional man years. Of this number 2.9 is devoted to dairy; 1.6 to beef; 1.0 to swine; 0.4 to sheep; 3.1 to poultry; 0.5 to materials and designs for heat control in livestock structures; 1.0 to reducing insecticide residues in animal products; and 0.8 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 19.1 professional man years divided among subheadings as follows: Dairy buildings 2.7, beef buildings 2.2, swine buildings 4.5, and poultry buildings 9.7. Part of this work is in cooperation with USDA. An estimated 4.3 professional man years of research on equipment for environmental control in livestock buildings are reported in Area 13.

Dairy building studies are in progress to determine the relative merits of various systems of handling the dairy cow. Carefully controlled laboratory investigations are being conducted to develop data on the effect of environment upon the comfort, breeding efficiency and production of dairy cattle and to relate such data to housing needs. These studies are a part of Cooperative Regional Project NC-23.

Beef building research is in progress to determine the relation of animal productivity to modified local climatic environment. Measurements of heat and moisture loss from beef cattle under various stress conditions are being determined and these data are being used in the design and construction of structures to provide optimum environmental conditions.

Swine building studies to determine the relation of climatic factors to the physical well-being of swine are in progress. These data are being directly applied to problems of design of structures and equipment for optimum economic production. Special investigations are under way to evaluate effects of combinations of temperature and humidity on growth, reproduction and efficiency of production. These results will assist the establishment of design criteria for environmental controls and equipment for swine housing units. These studies also are a part of Cooperative Regional Project NC-23.

Poultry building studies in progress at many of the state stations are attempting to establish basic data on environmental adaptation criteria for poultry housing and functional design requirements. These investigations are concerned with such problems as measurements of the effects of light, air movement, temperature and humidity on economy of production of both broilers and layers. Data on these and other factors are guiding the systematic design and evaluation of new and improved poultry structures and equipment. These coordinated studies are a part of Cooperative Regional Projects NC-23 and NE-8.

In industry several manufacturers of metal and other types of pre-fabricated buildings have been actively testing the performance of their buildings for housing dairy and beef cattle, swine and poultry. Estimated annual expenditures in 1961 were equivalent to approximately 20 professional man years. Manufacturers of lumber, cement and other materials have been developing new materials, investigating their applications and determining construction techniques for their use. However, most of this research has been directed to supplying the larger markets provided in industrial structures and non-farm dwellings. Estimated annual expenditures directly benefiting farms in 1961 were equivalent to approximately 30 professional man years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Layouts, Equipment and Facilities for Increasing Efficiency of Dairy Operations. At St. Paul, Minn., basic work in cooperation with the Minnesota Agricultural Experiment Station on establishing time standards for dairy barn operations has been concerned with the search for suitable standards for coordinating data taken under differing conditions. Industrial engineering pace standards are not apropos when attempting to rate many farm operations.

Baled-hay-handling time standards determined on the project have been applied to the investigation of hay shed design. A number of methods for putting hay into pole hay sheds were studied to determine which was the most efficient. The selected method was then used to determine the time per ton required to place the hay in storage in sheds of various lengths and designs.

Also using standard data, the time required to climb a pile of bales each day and distribute the required number of bales was determined and a minimum time per cow was established. This analysis indicated that within ordinary limits, time and labor requirements for moving hay are affected more by the width (depth) of the building than by its height or length.

The studies show that the building design causes variations in the time required for putting the hay into storage of about the same magnitude as those which it makes in the time required to feed the hay out. The minimums for both do not necessarily occur in the same design.

A further analysis was made to determine the building costs of these hay storage structures. The complete analysis will be dependent upon a linear programming study which will include the effects of building costs plus the time and labor required for putting the hay into the building and feeding it out.

The establishment of time standards will eventually provide a basis for analyzing feeding and cleaning operations using tractors, self-unloading wagons and other power equipment.

Much work has centered on the development of methods suitable for analysis of building and yard arrangement with the prime effort being directed to the use of scale models and time standards. Investigations into the use of models have established a need for scale-model building components which can be incorporated into building design and location variations to meet a great number of layout requirements. This has been accomplished by the design of components including wall sections, floors and poles which can be assembled into pole buildings of various shapes and sizes for use as resting barns, hay sheds, and so on. Milking parlor layouts have been developed that will allow for model analysis of all possible door arrangements and most currently available equipment. However, a stockpile of models is needed to expedite this work, and as commercial sources have been exhausted all future models must be handmade.

An attempt was made at St. Paul to set up an ideal loose housing design for a herd of 100 milking cows. It was found that while layout principles for the milking herd itself are apparently well established, similar coordinated principles for young stock and dry cows are seriously lacking. For this reason the effort has been delayed pending making additional models and searching for more information on coordinating all facilities with the minimum of compromise. Working up this ideal layout has given further indication of the value of models for presenting a good, rapid, visual analysis.

At Davis, Calif., work has continued in cooperation with the Experiment Station, on studies of dairy layouts having herringbone milking parlors. Thus far the results indicate that double-four, double-five and double-six stall parlors are suitable for herds of up to 100 cows. Herds larger than that will require parlors of the double-eight or double-ten size. When the herd size reaches 400 cows or more it will probably require two parlors of this size to eliminate complications and delays in the holding-washing pens, movement lanes and corrals.

Advantage has been taken of a unique opportunity to obtain operational data on a "before-and-after" basis for two California dairies, making rather extensive changes in building layout. The "before" but not the "after" studies have been made. One dairy is moving to a new site where a complete new farmstead is being developed, in consultation with the U.S.D.A. research, and the herd is being expanded from 150 to 200 cows. This is the second major modification at this dairy within 10 years, and comparative data will be obtained on all three phases--the original floor level abreast milking room, a double-three elevated stall milking room, and the planned facility. The other dairy, with 400 cows in lactation, is converting from milking in a 60-stall string barn to milking in 3 side-by-side, double-three elevated stall milking rooms constructed in the old string barn.

Studies of chore time and travel in pie-shaped corral layouts were continued in California as such units were built and became available for study.

Bio-Engineering Studies of Dairy Cows. Basic fundamental studies on the relationships between environment and various dairy animal health and production factors were continued in the psychroenergetic laboratory at Columbia, Mo., in cooperation with the State Station.

Holstein milk production decline at high ranges of temperature and humidity combinations was shown to be correlated quite well with the United States Weather Bureau Temperature-Humidity Index (THI).

For example, a rise in the T-H Index from 75 to 80 would correlate with a decline of about 12 percent in milk production; a rise from 75 to 85 in the T-H Index, with a 25 percent decline. The study also showed that a cow producing 50 pounds of milk/day in a 65° F. environment will decline more in terms of pounds of milk/day than will a 30 pound/day cow, when subjected to high temperature-humidity conditions. Water consumption for individual cows increased significantly for all temperature increases; feed consumption decreased significantly in some cows, but not all, depending on the amount of stress the temperature-humidity conditions imposed on the individual cows.

In a controlled feeding study lactating Holstein cows were force-fed during exposure to a stress condition of about 85° F. air temperature in order to prevent normal decline in feed consumption at stress conditions. Analysis of data statistically indicated that high temperature depressed milk production, even though the feed level was maintained the same. At 88° F. air temperature maintaining the feed level above that of animals fed free choice did not increase body temperature enough to be statistically significant.

Preliminary tests in an acclimation study with six cows exposed to an 85° F., 50 percent relative humidity condition, after being at 65° F., 50 percent relative humidity, for 6 weeks showed increasing rectal temperatures for 7 to 10 days. After 8 to 25 days of exposure to the high conditions, rectal temperatures leveled off or decreased in 4 cows, but increased in the other two. Respiration rates maximized after 3 days at the higher condition, then leveled off. Pulse rates declined and were lowest after 11 days at 85° F. but increased almost to their initial level about the 18th day.

The dairy cows brought into the Laboratory for the temperature-humidity and acclimation studies were subjected to physiological evaluation tests, standardized with regard to environmental factors, as part of a long-range study of variability among individual cows for development of selection indices. The responses of the 12 cows tested at a condition of 88° F., 40 percent relative humidity show differences among individuals as great as 40 respirations per minute, 38 heart beats per minute, and 3.4° F. in rectal temperature.

Response of thermally-stressed non-lactating Guernsey cows exposed to chilled wall panels, under a shade with wall surface temperatures varying from 20 to 40° F. was significant at the 1 percent level. The chilled panels were effective in reducing respiration rate, skin temperature, hair temperature, and water consumption, but not effective in comparably reducing rectal temperature.

Field evaluations at Tifton, Ga., in cooperation with AH and the State Station, on the value of shades versus shades-plus-fans for lactating dairy cattle in hot, humid climates showed no benefit in a pen with fan. Average daily maximum and minimum temperatures during the test period (July 10 - September 17, 1960) were 90.2 and 70.6° F. Daily averages of daytime relative humidity and dry bulb temperatures were 63 percent and 85.3° F.

Two pens of 9 Jersey cows each at Tifton were held in dry lot except for milking from June 20 to September 4, 1961. One pen was provided shade only and the second had access to the breeze from a fan and a water spray, as well as shade. The shade in each pen was 16' x 48'. The daytime average temperature was 89.3° F. and relative humidity was 58 percent. There were no benefits to milk production from the fan and spray although the sprayed animals seemed more "comfortable". It was felt that both the spray and the increased air flow were inadequate.

Sixteen typical plans specifically for dairy cattle structures and related equipment and another 7 for either dairy or beef cattle were developed at Beltsville for the Cooperative Farm Building Plan Exchange as follows:

Dairy

| | |
|---|----|
| 3-in-line milking parlor and milkroom | 1 |
| Structures and arrangements for loose housing enterprises | 12 |
| Calf pen, the open type | 1 |
| Barns, especially for protective shielding from radioactive fallout | 2 |

Dairy or Beef

| | |
|--------------------------------|---|
| Feeding and watering equipment | 4 |
| Hay storages and feeding shed | 3 |

Corral, Shade and Cooling Studies with Beef Cattle. A study begun in 1959 in cooperation with the Imperial Valley Field Station, El Centro, Calif., used 12 pens and 5 animals per pen. The animals used in the 1959 and 1960 tests were Herefords obtained in the Imperial Valley; the 1961 animals were Herefords from the University's range 40 miles north of Davis. The treatments were: 90, 135, and 200 square feet of pen area per animal; 27 and 48 square feet of shade per animal; and, high- and low-energy rations. Previous studies have shown the need for shade in the Imperial Valley. The feeding trial was 84 days when the mean temperature was 90.7° F. and mean air velocity 2.2 mph. Initial weight per animal was about 540 pounds.

Combined analysis of the data for three years indicated for average daily gain:

- (a) No difference between 27 and 48 square feet of shade.
- (b) No difference between 90, 135 or 200 square feet of pen area.
- (c) Highly significant greater gains on high-energy rations.
- (d) Highly significant lower average daily gains in 1961 compared with 1959 or 1960.
- (e) No significant interactions between any of the factors studied.

It is therefore concluded that (a) during most years, an average shade area of 25 to 30 square feet per animal would be adequate for very hot dry areas such as the Imperial Valley; (b) total pen area as low as 90 square feet per animal is not so restrictive as to limit feed intake or average daily gain.

Basic investigations at El Centro on the effect of exterior surface cooling of beef cattle on weight gains and physiological responses yielded no conclusive findings and will be continued. A "head cooler" feed bunk 12 feet long, enclosed in a box to permit recirculation of cooled air, was constructed and fitted with 5 stanchions so the animals could be locked in when necessary. Five Hereford steers ate from this during the 84-day beef cattle test period. Although the equipment did not function as planned and the design air temperatures were not maintained, gains averaged 2.24 pounds per day, and were comparable to the gains of all the other beef cattle on test during the period.

Field evaluations of shades for beef cattle on pasture and in dry lot at Tifton, Ga., were made in 1960 in cooperation with the State Station. Weight gains of 36 steers, weighing about 644 pounds initially, were observed during the 154-day fattening period, April 19 to September 20. Four lots of cattle were used, two in dry lot and two on pasture. There was a shade in one dry lot and one pasture. Steers in all lots received full feed of ground snapped corn and cottonseed meal; those in dry lot received Coastal Bermuda hay. The pasture was Coastal Bermuda grass. Cattle in the pasture with shade made slightly higher gains than those without shade, but this finding was reversed in the dry lots.

Growth rates of 24 steers grazing on pasture, with and without shade, were observed during the same 154-day period. The study did not show that the shades increased the rate of gain under Georgia conditions which are much less severe than those at El Centro.

Typical plans for corral and feed lot, dipping vat, and pen for truck scales specifically for beef cattle were developed at Beltsville for the Cooperative Farm Building Plan Exchange. Other plans for dairy or beef cattle are listed on page

Pen Space Requirements for Confinement-Raised Hogs. In the University hog barn at Davis, space allotments of 5, 10, and 20 square feet per pig (excluding self-feeder space), and group sizes of 3, 6, and 12 animals per pen, were used in a 3 x 3 factorial design. There were 3 pigs per pen in pens of 15, 30 and 60 square feet area; 6 pigs per pen in pens of 30, 60 and 120 square feet area; and 12 pigs per pen in pens of 60, 120 and 240 square feet, respectively. Automatic waterers were used, one feeder opening for each three pigs was allowed, and initial weight of the pigs was about 80 pounds. Pigs with 20 square feet each gained weight more rapidly than those confined to 5 or 10 square feet ($P < .01$)^{1/}. Pigs with 3 per pen consumed more feed daily than either 6 ($P < .05$)^{2/} or 12 per pen ($P < .01$)^{1/}. Pigs with 5 square feet each required more feed per unit gain than those with 20 square feet ($P < .01$)^{1/}, and pigs in groups of 3 per pen used more feed per unit gain than those with either 5 ($P < .01$)^{1/} or 12 per pen ($P < .01$)^{1/}. Curves have been plotted from these data showing optimum space, depending upon feed and building costs.

Temperature Requirements and Control for Hogs. Studies to determine the benefits of sprays and wallows on weight gain of swine were conducted at Davis, Calif., in the summers of 1960 and 1961. The 1961 study was conducted in five concrete-floored pens from June 21 to August 27. Sprays were operated from 10 a.m. to 8 p.m. The respective weight gains (lb./day) and feed conversion (lb. feed/lb. gain) were: Control, 1.29 and 3.75; unshaded wallow, 1.39 and 3.68; shaded wallow, 1.56 and 4.16; unshaded sprays, 1.53 and 4.24; shaded sprays, 1.52 and 3.86. Difference in gain at 1 percent level was significant only between controls and all other treatments. At 5 percent, the gains of the control and unshaded wallow pens were significantly less than all other treatments. Average temperature and relative humidity during the period were 77.1° F. and 49.5 percent. The maximum and minimum temperatures were 96.8 and 60.1° F. and the corresponding relative humidities 26.0 and 76.6 percent.

Similar results with wallows were obtained in 1960. Cooling the wallow water about 17° F. by passing it through a cooling tower provided no significant benefit over uncooled water.

^{1/} One chance in a hundred of not occurring this way.

^{2/} Five chances in a hundred of not occurring this way.

Daily observations of behavior of growing pigs subjected to 4 heat relief measures at Davis, Calif., yielded the following information. Observations were made at 2-hour intervals for a 50-day period.

Where shade was the only relief measure it was used about 80 percent of the time from 7 a.m. to 3 p.m. Addition of a wallow reduced the time spent in the shade. Use of portable houses (3-sided, wooden floor, metal roof) was relatively low as compared to fabric shades and other shade on the concrete floor. Use of heat relief measures increased rapidly when the temperature went above 70° F. The air-conditioned house was used about 60 percent of the time during hours of observation. An increased weight gain in all treated lots was not correlated with any behavior pattern.

The importance of suitable shade on summer days with temperature over 70° F. is indicated. The use of other relief measures such as wallows also is of importance.

An effort to duplicate in the field the weight gains of swine raised at optimum temperature growing conditions within the laboratory, was made at El Centro, Calif., in 1960 and 1961. In 1960, pigs in each of two open pens had access to 6' x 10' x 4' high insulated buildings that provided a 75° F. environment. Temperature in one house was maintained by blowing refrigerated air through it (no recirculation). Water-cooled ceiling and wall panels cooled the other. Air velocity through the air-cooled house was about 100 fpm; in the radiant-cooled house it was essentially nil. Rate of growth and feed consumption of pigs (8 per pen) with free access to these houses were compared to those of pigs with access to a shaded wallow during an 84-day summer test. Average weight of the pigs was about 80 pounds at the start of the test on June 27. Rations were self-fed outside cooling structures.

Average maximum, minimum, and mean temperatures during the period were 107.7, 75.6, and 90.7° F. Average daily gains were 1.42 pounds (air-cooled house), 1.36 (panel-cooled house), and 1.49 (shaded wallow). The respective feed consumption per unit of gain was 4.12, 3.97, and 4.00 pounds. The differences between means for average daily gain, carcass yield, backfat thickness, or average daily feed consumption were not significant. It has been suggested that the change in environment was too great when the animals moved out to eat. An activity check indicated that the house animals ate mostly between 4 and 8 a.m., whereas wallow pigs seldom ate between 7 p.m. and 7 a.m.

In 1961, the houses were lengthened from 10' to 14' to make room for a feeder and water cup in one of them. The pigs in the other house had to leave the cooled house for feed and water. Each house was used by 8 pigs from June 22 to September 6. A shaded wallow was used in the control pen. Average period temperatures were: Outside, 89.3; cooled house with feeder inside, 72.3; cooled house with feeder outside, 69.7. Differences in daily gains, yield, and back-fat were not statistically different. The actual gain of the pigs in the cooled houses averaged 1.62 lb./day and that of the control pen averaged 1.52.

A series of feeding trials, in cooperation with a producer near Escalon, Calif., was started in a field study of three different types of housing and three or four levels of feeding. The housing is a McMaster house with insulation and evaporative cooling, a McMaster house with no sidewalls but an insulated roof, and an open shed with aluminum roof and open side south. In each house several levels of feeding were used--90, 81, 73, or 65 percent of the ration suggested by the National Research Council. After the first test the 65 percent level was discontinued. For each test, each pen had 10 pigs that were started at about 100 pounds and fed to market weight. It is planned that these tests will cover each season of the year. The first test was started March 23, 1961, the second on July 14, and the third on December 27. The latter test ended March 26, 1962, and the results are not included in this report. For the first two tests there was no significant difference due to housing, but results of all levels of feeding were different from all other at the 1 percent level, with the greatest gain due to the highest level of feeding, but a few pounds less feed required per 100 pounds of gain at 73 percent of the National Research Council ration level. These tests will continue.

Typical plans for a fattening unit and an electric brooder for swine were developed at Beltsville for the Cooperative Farm Building Plan Exchange.

Plastic-Roofed Sheep Shelters. Studies at the Hopland Field Station in California, cooperative with the State Station, were continued with the installation of a new cover material consisting of black and white polyethylene film on both sides of heavy kraft paper. A new design of curved roof trusses for low-cost shelters was developed and structurally tested with installation and service-testing planned for next year.

Ten typical plans for sheep and lamb shelters and feeders and 6 for miscellaneous items of sheep equipment were developed at Beltsville for the Cooperative Farm Building Plan Exchange.

Environmental Requirements and Control for Poultry. Calorimeter studies at Beltsville, in cooperation with AH, were resumed after reassembling two calorimeters that were moved to the new AE Poultry Environment Laboratory. Each calorimeter was enclosed in a separate room for more precise control of temperature. Two special cages (with droppings pan underneath) were constructed to handle groups of all classes of poultry. One of these will be installed in each calorimeter to study birds using a common feeder and waterer. During the year a 24' x 40' addition was made to the Laboratory and within it five chambers (each 7 feet x 11 feet x 6 feet) were erected to study long-time effects of controlled environment on growth and egg production. The necessary wiring, piping, and installing of refrigeration and air handling equipment for environmental control is now in order.

Calorimetric data for caged White Leghorns were analyzed, published and successfully used to check studies of experimental windowless and solar poultry houses. The heat balance for windowless houses was within expected accuracy. For the solar house, however, a heat balance showed, at times, a heat output about 20 to 30 percent greater than heat input by the birds. Further studies are needed to assess in-place U values, infiltration, exfiltration, solar heat pick-up, and other factors.

Short-run heat and moisture production measurements were made on Arizona Short-Combed White Leghorns (heat resistant strain). These birds evaporated about 15 percent more moisture from lungs and/or bodies at 85° F. than the Beltsville-bred Short Combed White Leghorns.

Turkeys, in tests of one-week periods at temperatures of 65° F. and 80° F., had heat production rates, per unit live weight, that approached those of the New Hampshire x Cornish laying hens reported in ARS 42-43. During the lighted hours at 65° F. both toms and hens emitted about the same total heat. At night the toms and hens produced 25 percent and 10 percent less heat per pound, respectively, than the NHxC chickens. At 80° F., the toms and hens emitted about 10 and 20 percent less heat, respectively, per unit of live weight than the NHxC chickens. During the dark hours both the sexes produced 10 percent less heat per pound than the laying chickens.

Studies of the influence of temperature and ventilation on development of sinusitis in turkeys were conducted at St. Paul, Minn., in cooperation with the State Station. In the first of 2 tests, one heated and one unheated pen, each with about 50 birds, were used; in the second test, two heated and two unheated pens, each with 80 birds, were used. Ten birds in each pen were inoculated with type S₆ PPLO virus. In both tests the rate of natural transmission from inoculated to non-inoculated birds was nearly 100 percent as determined by PPLO serum plate test. In the first test 20 percent of the inoculated and 3 percent of the non-inoculated birds in the heated pen developed lesions that would have caused condemnation; corresponding data for the unheated pen were 33 percent and 11 percent. In the second test, 16 percent of the inoculated birds in the heated pen and 29 percent of those in the unheated pen were condemned. Data on the non-inoculated birds are not available.

Plans for the poultry disease laboratory at Athens, Ga., for which funds were appropriated in FY 1961, were prepared in cooperation with ADP, AH and the College Agricultural Experiment Station. The principal area of agricultural engineering responsibility is the relation of housing environment to poultry disease. Close assistance was given the architect in preparation of the laboratory plans. The contract for construction was awarded on February 12, 1962, and the project is to be completed in 365 days. Facilities include two buildings for environmental studies, one of which is to contain 12 environmental chambers. Development and construction of these chambers is the responsibility of AE. Tentative designs have been prepared and a prototype is being constructed.

Field observations of poultry housing in Mississippi to develop data on the relationships of poultry house design, construction and management to airsacculitis, were initiated in February 1962, in cooperation with AH, ADP, and the State Station. These studies are preliminary to preparation of final plans for the research program in the projected poultry disease laboratory at State College, Miss. No findings have developed as of the reporting date.

Typical plans for a stretched wire cage laying house for the Northeast and another for the Southwest were developed at Beltsville for the Cooperative Farm Building Plan Exchange.

Materials and Designs for Heat Control in Livestock Shelters. Radiation characteristics of building materials are under study at Davis, Calif., in cooperation with the State Station. Fifteen additional materials and treatments were tested to determine their "effectiveness" (their value, relative to aluminum) in reducing the radiant heat load on animals under them. This makes a total of 51 materials tested.

Sloping roofs (3" in 12") of aluminum, galvanized steel, and masonite were oriented with their "high" side in each of the cardinal directions. It was found that the radiant heat load under a sloping roof with the "high" side facing north was less than for any of the other orientations, and less than under a flat shade. This was true for shades covered with aluminum or galvanized steel; under the masonite the high side west was coolest but the shadow was small during the hot part of the day. The shadow under a sloped shade with the high side north was 10 percent or more (depending on slope and time of year) greater than under a flat shade, or a sloped one with other orientation, during the four mid-day hours. For this reason a sloped shade with high side north could be expected to provide the coolest environment--compared to a flat shade or shades sloped in other directions.

Studies were continued using four 1/3-scale model hog houses for comparison of (1) various orientations, (2) flat and 2" in 12" roof slopes, and (3) the number of walls on the structure. As before, the comparisons were made on the basis of the radiant heat load, RHL, within the various models. Over a 24-hour period, orientation was found to have little effect on RHL; however, for the period 11 a.m. to 4 p.m., northern orientation of the open side was better than south or east orientation. For the 11 a.m. to 4 p.m. period, the sloped roof with the open side north had the lowest RHL; the sloped roof with the open side south had the highest RHL. Results of the study on effect of walls indicated that the RHL increased sharply with fewer walls (particularly with no walls) and the variation in RHL about the mean increased with fewer walls. An attempt was made to relate various wall and roof treatments tested in 1959 to an "effectiveness" scale, but results were inconclusive. This work will be continued.

While investigating the thermal models, it was discovered that metal roof temperatures varied with roof area, that is, with size of roof (smaller roofs were cooler). A field study in 1959 emphasized the action but there were too many uncontrolled variables for an accurate analysis. This led to a laboratory investigation using a low-level (low-speed) wind tunnel with a solar radiation simulator. A series of runs were made using an 18" x 48" test plate of galvanized steel mounted on a 2 1/2" high insulation stack placed on the floor of the tunnel in turbulent air flow. Variation of Δt (difference between plate temperature at a given point and the mainstream air temperature) along the plate length followed quite closely the air velocity pattern over the plate, indicating plate temperature to be primarily a function of convective cooling. Other results indicated a 1° F. rise in air temperature produced a 1° F. rise in plate temperature, regardless of air velocity.

Following are findings of tests with various types of roofs:

(a) Sloped - essentially no differences occurred in convective heat transfer by forced air flow over roof sections of 4" in 12" and 2" in 12" slopes, but both slopes were slightly cooler than a similar flat roof section; (b) gable - on the windward roof slope (2" in 12") the convective cooling effect was quite similar to that of the sloped roof test--on the leeward portion of the roof section considerable eddying of air flow occurs before normal convective cooling is again established; (c) "sawtooth" - when a roof section was oriented so the air flow first struck the low edge of the "sawtooth", the average convective cooling effect is very nearly the same as for the sloped roof test. Where the air flow struck the high edge of the "sawtooth" first, an increase in convective cooling occurs (attributed primarily to increased turbulence in the air flow over the roof section); (d) corrugated - air flow parallel to the corrugations indicated a small increase in convective cooling evidently caused by increased turbulence due to the corrugations (no appreciable differences in convective cooling were apparent when surface temperatures at the top and bottom of corrugations were compared). Air flow perpendicular to the corrugations showed increased convective cooling occurs at points more than 24" downstream from the leading edge of the roof section; (e) painted - roof sections painted flat black and white were compared to unpainted with respect to the patterns of convective cooling along the surface, and all were found to follow the same general pattern; and (f) effects of major climatic factors on metal roof temperatures - three climatic variables (air temperature, wind velocity and solar radiation) accounted for 72 to 94 percent of the variation in roof surface temperature, depending on roof size; air temperature was found to account for the major portion of the variation. Analysis of data for the above tests was done at Columbia, Mo.

Field observations of shade characteristics were made at Tifton, Ga. Three 12' x 24' shades were constructed of corrugated galvanized steel on treated lumber. Each shade was a different height--6, 9, and 12 feet high. A fourth shade 16' x 24' x 11' high, on a pipe frame, was covered with 70 percent woven saran fabric. Black globe and air temperatures observed hourly (10:30 a.m. to 3:30 p.m.) on two consecutive days in September averaged:

| | Galv. 6 ft. | Galv. 9 ft. | Galv. 12 ft. | Fabric 11 ft. | No Shade sun |
|-------------|----------------|----------------|-----------------|------------------|-----------------|
| | <u>°F.</u> | <u>°F.</u> | <u>°F.</u> | <u>°F.</u> | <u>°F.</u> |
| Black globe | 94.1 | 96.0 | 97.5 | 101.0 | 117.3 |
| Air | 89.1 | 90.0 | 90.4 | 90.5 | 94.8 |

Reducing Insecticide Residues in Animal Products. At Kerrville, Texas, equipment and procedures for fundamental studies on reducing chemical hazards associated with the control of livestock insects are being developed, in cooperation with ADP and ENT, ARS.

A metal building, 36' x 60', to house shop, office and laboratory was completed and equipped in January 1962.

Research studies were then started to determine the relation between the deposition of insecticides on animal hair coats and spraying and dusting variables such as particle size, particle velocity, spray viscosity, surface tension and others. A preliminary test indicated that only about 25 percent of a one-gallon application of water containing 2.3 percent copper sulfate will remain on a Hereford cow even when the cow has a winter hair coat. As this work progresses, effects of animal characteristics such as length, weight and density of hair coat will also be considered.

Other studies have been set up to determine methods of measuring and controlling the distribution and uniformity of insecticidal depositions on livestock.

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AREA 10, CONSTRUCTION STANDARDS, WATER SUPPLY,
WASTE DISPOSAL, AND FARMSTEAD PLANNING

Problem. The inventory value of farm buildings in the United States exceeds \$28 billion. During 1960, more than 1/2 billion dollars were spent on repair and maintenance of these buildings and an additional 1 1/2 billion was spent for new construction, additions, and major improvements. The construction of many of these buildings is wasteful of materials. The strength of structural members is frequently much greater than the joints that connect them. Assumed loads are sometimes unrealistically high and at other times so low that failures occur. Better information on the actual loads--contents, wind, and snow--is needed. Rural fires account for 800 deaths and 175 million dollars worth of property damage annually. Information is needed on means of reducing these losses without imposing excessive expense on construction.

In many localities urban building codes that may be unduly restrictive are being extended to cover farms. The hazards of public occupancy and damage to the property of others are not present to the degree that they are in urban areas. Those who draft building and fire codes need design information that would be realistic for farms.

An adequate supply of satisfactory water is essential to the farmstead. Automatic running-water systems, more water-using equipment, new uses for water, higher standards of sanitation, and other factors are continually increasing the demand for water on the farmstead--both in quantity and quality. The "old well" is less and less able to satisfy the demand. Some farm operators have been forced to buy water by the tank or truck load at considerable cost; others are developing farm ponds as sources of farmstead water; some continue to operate with a supply that is becoming less and less adequate.

Surface waters normally require disinfection as a safeguard against water-borne diseases such as typhoid, dysentery, other gastro-intestinal disorders, and infectious hepatitis. Often they also require filtration and other treatment to remove undesirable foreign material. Deeper ground waters are often highly mineralized (hardness, iron, sulphur, and others), and expensive or impossible to treat adequately. Data on water demands and water systems requirements of the modern farmstead are needed to guide farmers in planning water systems and selecting equipment, to enable extension workers to adequately advise farmers, and to guide equipment and appliance manufacturers and sanitary code-making bodies. Simpler, more reliable, and less costly methods and equipment are needed for treating farmstead water supplies to improve their quality.

Disposal of organic wastes--principally sewage and manures--is becoming more and more of a problem on the modern farmstead. It has been estimated that, in 1959, the cattle, hogs, horses, sheep, and poultry on farms in the United States produced more than 2 billion tons of manure. The problem is particularly acute with respect to confinement-type livestock operations on the fringes of metropolitan areas--where the total amount of manure is concentrated in the confinement area. Under these conditions it is difficult to avoid creating a sanitation hazard or a public nuisance. Economical, sanitary means of disposition need to be developed. Among means to be investigated are lagoons, irrigation systems, subsurface absorption systems and reclamation. Development of improved methods for disposing of sewage in those rural areas where conditions are adverse to the conventional septic tank system (high ground water, shallow rock, non-absorptive soils, restricted areas) is needed.

The arrangement plan of the farmstead has an important bearing on its efficiency, appearance, and livability. For example, convenient locations for feed and bedding storage ease the distribution chore. A 40-cow dairy herd will use approximately 240 tons of silage, 60 tons of grain, 40 tons of hay, and 20 tons of bedding annually. Research is needed to evaluate the various planning factors in the light of current equipment and practices and to develop planning principles and guidance materials for the benefit of farmers--particularly those contemplating changes.

A 1957 survey of about 25 well-informed leaders of the agricultural community in each state reported the following as the most urgent problems needing solution:

1. How to adapt existing buildings for more efficient production.
2. Lower cost, more efficient, and more flexible buildings for tomorrow.
3. Engineered farmstead design.
4. Mechanization of materials handling.
5. Better utilities--water supply, wastes disposal, and electric service.

USDA PROGRAM

This is a continuing long-term program involving engineers and architects engaged in basic and applied research on structural aspects of farm buildings, farmstead water supply, farmstead wastes disposal and farmstead planning. It is cooperative with selected State Agricultural Experiment Stations.

Meteorological factors affecting the design of farm structures, such as climate and weather (wind, storms, frost, etc.), are studied at Beltsville, Md., and selected field locations. A contract has been let to the Weather Bureau, USDC, for data on snow load probabilities.

Standards, such as serviceability and safety, for design of farm buildings are studied at Beltsville, Md., and selected field locations. Liaison is maintained with the American Society of Agricultural Engineers, American Standards Association, National Safety Council, National Fire Prevention Association, and other organizations concerned with standards and safety in farm structures.

Materials and construction methods for farm buildings are studied at Beltsville, Md., at Blacksburg, Va., in cooperation with the Virginia Agricultural Experiment Station, and at State College, Miss., in cooperation with AH and the Mississippi Agricultural Experiment Station.

Water supply and wastes disposal for the farmstead are studied at College Park, Md., in cooperation with the Maryland Agricultural Experiment Station. Liaison is maintained with the Public Health Service, the Water Systems Council, American Society of Agricultural Engineers, and other organizations concerned with rural sanitation.

Farmstead planning studies are made at Beltsville, Md., at St. Paul, Minn., in cooperation with the Minnesota Agricultural Experiment Station, and at Davis, Calif., in cooperation with the California Agricultural Experiment Station.

The Federal effort in this research area totals 6.7 professional man-years. Of this number 0.6 is devoted to meteorological factors; 0.3 to standards for serviceability, safety, etc.; 2.4 to materials and construction methods; 2.0 to water supply and wastes disposal; 0.9 to farmstead planning; and 0.5 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 11.6 professional man-years divided among subheadings as follows: Building materials, 1.5; construction methods, 4.9; plan development, 1.0; water supply, 1.3; manure and waste disposal, 1.5; farmstead planning, 0.8; and fencing, 0.6.

Building materials studies are in progress in the North Central, Northeastern, and Southern Regions to determine the suitability, value, and limitations of wood poles for framing and of aluminum, wood, concrete, and asphalt in the construction of farm buildings. The work in the North Central region (1.0 professional man-year) contributes to Cooperative Regional Project NC-9, "Utilization of Materials to Meet Housing Needs of Rural Families". Construction methods investigations are in progress in all four regions to improve the functional performance of farm structures through careful analysis and tests of certain of the major structural components of buildings. Investigations are under way on rigidity of certain joint designs and on designs for new trusses, frames and panels incorporating poles and native materials.

Water supply investigations are in progress in the North Central and Southern Regions to provide potable water supplies for farm home use from ponds and to reduce mineral content of sub-surface waters. These investigations are seeking economical ways to combine filters, membranes, sterilization apparatus such as chlorinators and germicidal lamps and ion exchange equipment. Manure and waste disposal investigations are in progress in the North Central, Northeastern, and Western Regions on the use of lagoons for disposing of these wastes. Included in the studies are design and development of special equipment and facilities for automatic transfer of the material to the disposal facility and cooperative laboratory examinations to determine the bacteriological and bio-chemical aspects of the waste materials. The studies are a part of Cooperative Regional Project NC-48, "Development of Materials Handling Systems for North Central Farms".

Farmstead planning work is conducted in the Northeastern and North Central Regions and is concerned largely with the Farm Building Plan Exchange, in cooperation with USDA or by participation in the Midwest Plan Service. Limited studies are in progress in the Northeastern Region to find materials and installation methods for more economical paving of roadways, lots, and larger areas around the farmstead.

In 1961, the lumber, metal buildings, portland cement, and clay building products industries were active in developing and testing applications for their respective products in all types of construction--mostly for the larger markets provided in industrial and commercial structures and non-farm dwellings. Estimated annual expenditures by these industries in this research area were estimated to be equivalent to 15 professional man-years.*

Water supply equipment manufacturers and trade associations are engaged in product development and improvement research on broad lines of equipment--only a small portion of which has specific application to the farm. It is estimated that less than five professional man-years are devoted to this portion.

Wastes disposal equipment manufacturers devote little or no research effort specifically to disposal of wastes from farm houses or service buildings. A number of manufacturers of chemical toilets, incinerators, patented sewage disposal devices and related items are engaged in development and improvement research on some products that have some application to the farm. The estimated effort is less than 5 professional man-years.

Farmstead planning research in industry is estimated at less than 5 professional man-years on the part of a few consulting agricultural engineers who combine a small measure of research with their consulting, and a few manufacturers of materials handling equipment and farm buildings who are conducting product development or improvement research related to farmstead planning.

Fencing manufacturers, principally steel fencing, are conducting an estimated less than 2 1/2 professional man-years of product development and improvement type of research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Meteorological Factors. A method of using weather data for livestock shelter design was developed and defined using Des Moines, Iowa, weather observations as a demonstration sample. Observed data were analyzed and tabulated to show frequency of occurrence of certain critical temperatures, relative humidities, temperature-humidity combinations, winds, cloud cover, and precipitation. These data enable intelligent consideration of (1) the degree of enclosure required for the class of livestock and locality under consideration; (2) the structural strength required for the locality; and (3) the selection of the site for the structure.

*Fire insurance companies sponsor research on fire retardance of building materials and construction. Fire-fighting equipment manufacturers study product development. Activities applying to this research area are estimated to be equivalent to less than 10 professional man-years per year.

Snow load probabilities for different climatic regions of the United States are being developed under a contract to the U. S. Weather Bureau. Ten years of Weather Bureau records on water equivalent of snow pack are being used to prepare maps showing the pounds per square foot of snow load that could be expected at various recurrence intervals--5 years, 10 years, etc.--at their first order weather stations. Special treatments for those Southern regions not having snow every year are in progress.

Construction Standards. Tentative standards for design stresses and design loads for farm buildings have been developed in cooperation with the Construction Standards Committee of the American Society of Agricultural Engineers. These standards recommend adoption by reference of recognized design stresses for the various conventional construction materials.

Materials and Construction Methods. Soil-cement building block durability studies at Beltsville, Md., revealed that the rate of deterioration of the blocks was declining. After 4 years in place the blocks were still satisfactory. Deterioration is measured by comparing annual impact-rebound hammer readings.

Stressed skin panels made of 2" semi-rigid insulation faced on both sides with 1/2" of reinforced portland cement mortar were manufactured and tested. A procedure for prestretching galvanized reinforcing for exact placement and elimination of shrinkage cracks was developed and appears very satisfactory. Tests of panels cast in this manner show that the panels will carry 40 pounds per square foot uniform load, which is sufficient for lateral wind velocities. Studies of the effects of temperature differential reveal that a 40° F. temperature differential causes about 0.1" midspan deflection. Investigations using latex modified mortar for the skin were promising. Panels have been cast with embedded resistance heating cable for supplemental heat in livestock structures, and appear to be satisfactory.

A small structure was built on the Agricultural Research Center at Beltsville to evaluate erection and panel joining procedures. Caulked horizontal joints appear to be the most practical. Observations on this structure will be made to observe durability. Erection of this structure at the Agricultural Research Center provided a new opportunity for research on HP (hyperbolic paraboloid) roofs. A loading test of a HP roof made of plywood strips with lapped joints fastened with bolts, withstood normal design loads.

Two additional tests of a quadrant of a 16' x 24' roof proved that a HP shell of 1/4" tempered hardboard can resist a load of 30 pounds per square foot and satisfactorily recover. These tests gave design confidence in methods of orienting the strips and fastening the joints. Consequently, an HP roof for the building was completed with two sheet materials of two different strip widths used as a structural skin and three different elastic roof coatings in two colors for weathering property studies. Roof movement was checked periodically at 41 points to study deflections under various conditions of weather and snow loading. Structural and weathering performance appears to be entirely satisfactory with the possibility that edge members may be over-designed. They were designed as a compromise between conventional and HP edge member theories to compensate for secondary stresses found in prior test shells.

Two new principles of use of doubly curved surfaces (HP and hyperboloid of one sheet) were developed to (1) minimize horizontal thrust on supporting columns and (2) to utilize identical warped surfaces for construction of integral side wall and roof. A public patent is pending on these two developments.

Limited information on the rotational strength of nailed joints has been obtained in a cooperative effort with the Virginia Agricultural Experiment Station. Seventy-two tests were conducted on joints in 2 x 4's, 2 x 6's, and 2 x 8's. Correlation between joint rotation and load indicated that bending moment resistance of nailed joints can be mathematically computed with confidence.

Full scale tests of rigid timber frames were conducted in cooperation with the Virginia Agricultural Experiment Station. These tests resulted in some design refinements and greater confidence in frame structural behavior under loading.

Studies on the influence of poultry housing materials and construction methods on incidence and transmission of poultry diseases were initiated in Mississippi in February 1961, in cooperation with the Mississippi Agricultural Experiment Station. No results are as yet available.

Water Supply and Wastes Disposal. Studies on farmstead water demand and requirements for water supply systems are in progress in Maryland, in cooperation with the Agricultural Experiment Station. An automatic data recording system has been developed and satisfactorily field tested on a 40-cow dairy farm. The system both collects and tape records water use data automatically. It has 12 counters which can continuously measure and record the water use at 12 points in the system.

Preliminary analysis of data gathered during the system check-out showed that 47 gal./person/day were used in the farm house, 4.3 gal./cow/day in the milk room and 11.0 gal./cow/day in the stall barn--an indication that the dairy herd is the major water user on the dairy farm.

Wastes disposal studies in cooperation with the Maryland Agricultural Experiment Station have indicated that a properly designed "lagoon" could provide an economical method of handling and disposing of livestock manures. However, observations of a number of farm lagoons which are not operating properly show need for the establishment of design factors which include the area necessary per animal unit as well as the depth necessary for proper bacterial action.

In cooperation with the Maryland Agricultural Experiment Station a holding trench-lagoon combination was designed and installed on the farm of a cooperator. The holding trench is adjacent to a feeding floor for hogs and is large enough to hold 10 to 14 days' flushings from that floor. When full, a bottom plug is pulled and the contents are drained into a pond used as a disposal lagoon, having an area of 100 square feet per animal. Observations thus far have noted no fish kill and the area immediately adjacent to the point where the effluent enters the pond has remained open during the winter while the rest of the pond and the holding trench were frozen over. Although some bedding was flushed into the system, none was observed floating on the pond as has been observed where the flushings go directly to the lagoon. Further work will determine the effect of the holding trench in the initial digestion of the waste material.

Instruments have been designed to determine the biochemical oxygen demand of various agricultural waste materials and to determine the sulfate content of the water used in flushing material into the lagoon. This factor may be responsible for a buildup of the sulfate content in the lagoon and causing an odorous condition.

Farmstead Planning. Use of models for planning farmsteads and analyzing layouts is being investigated at St. Paul, Minn., in cooperation with the State Agricultural Experiment Station. Efforts to establish a suitable stockpile of appropriate models of farmstead components (houses, service buildings, feeding structures, fences, handling equipment, etc.) have exhausted commercial sources and all future models will have to be made on the project.

Information obtained on pie-shaped (or wagon wheel) layouts for dairy cattle in cooperation with the California Agricultural Experiment Station has been applied to the initial design of 3 pie-shaped beef feeding layouts. Feeding area is at the hub and corral fences extend outward in a pie-shaped manner. Studies of pie-shaped corral layouts for dairy handling were continued and principles established thus far were applied to the design of 5 dairy layouts in California.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Meteorological Factors

Hahn, LeRoy, Thom, H. C. S., and Bond, T. E. 1961. Basic weather data for livestock shelter design. Paper No. 61-923, presented at Winter Meeting, ASAE, Chicago, Illinois, December 12-15.

Teter, N. C. and Yeck, R. G. 1961. Effect of wind and sunshine on thermal design of farm homes and service buildings. Paper No. 61-310, presented at North Atlantic Section Annual Meeting, ASAE, New Brunswick, Canada, August 20-23.

Materials and Construction Methods

Kent, T. E., Liu, R. C., and Teter, N. C. 1960. Research results on soil-cement building blocks. Paper No. 60-407, presented at Summer Meeting, ASAE, Columbus, Ohio, June 12-15.

Kent, T. E., Felton, K. E., and Merrick, C. P. 1961. An evaluation of mixed-in-place portland cement concrete for barnyard and feed-lot pavement. Maryland Agr. Expt. Sta. Misc. Pub. 426, June.

Kent, T. E., Liu, R. C., Teter, N. C., and Meador, N. F. 1961. Grout surfaced, insulated, stressed skin panels for farm buildings. Paper No. 61-913, presented at Winter Meeting, ASAE, Chicago, Illinois, December 12-15.

Liu, R. C., Kent, T. E., and Teter, N. C. 1960. Economic design for optimum winter production of laying hens. Paper No. NA 60-50, presented at North Atlantic Section Meeting, ASAE, Amherst, Massachusetts, August 22-24.

Liu, R. C., Teter, N. C., and Kent, T. E. 1962. A hyperbolic paraboloid roof. Transactions of the ASAE, pp. 68-74.

Water Supply and Wastes Disposal

Bailey, W. A. 1960. Fan and pad system of cooling greenhouses and other farm buildings. Paper No. NA 60-48, presented at North Atlantic Section, ASAE, Amherst, Massachusetts, August 22-24.

Eby, Harry J. 1961. Design criteria and management for manure lagoons. Paper No. 61-935, presented at Winter Meeting, ASAE, Chicago, Illinois, December 12-15.

Farmstead Planning

Cleaver, Thayer. 1960. Designing pie-shaped dairy corral layouts. Agr. Engr. Jour. 41(9):608-610, September.

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AREA 11, ELECTROMAGNETIC AND ULTRASONIC ENERGY FOR
INSECT CONTROL AND OTHER FARM USES

Problem. Electromagnetic radiation has many established farm uses but research indicates many other highly useful potential capabilities in farm production, such as killing insects harmful to stored grain without leaving residues. Annual losses in recent years due to insects in field crops stored on the farm approximate 200 million dollars. The use of chemicals in agriculture is increasing rapidly with United States' pesticide sales increasing every year for the past eight years from 161 million dollars in 1953 to 300 million in 1961. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. Since there is zero tolerance of DDT in milk, there is need for an electrical or physical means of controlling flies in and around dairy barns and milk houses. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant.

USDA PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the Experiment Stations of eight States. Electrical and physical methods for corn borer control are studied in Iowa, cotton insect control in Texas, with the project contributing to Regional Research Project S-37, Basic Factors Involved in Control of the Pink Bollworm. Electrical and physical methods of tobacco insect control are studied in North Carolina and Virginia, also peanut insect control in Virginia, and vegetable insect control and light trap design in Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Fly control in dairy barns is studied at Beltsville, Maryland.

Research on electromagnetic energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seeds and other farm products in Tennessee and Washington.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 9.9 professional man-years; of this number 5.2 is devoted to electrical and physical insect control, 4.0 to radio-frequency, glow discharge plasma, and electrostatic equipment for product treatment, and 0.7 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 1.7 professional man-years engaged in this field divided into the following sub-areas: equipment for control of insects in grain and seeds stored on the farm 0.5, electrical and physical means of insect control 0.7, and conditioning farm products 0.5. Part of this research is cooperative with USDA. Insect attraction tests include measurements of the effectiveness of various electric lamps that emit narrow bands of the light spectrum. Research is underway to explore the possibilities for attraction and destruction of stored product insects through the use of electromagnetic radiation. A study of the effects of electromagnetic radiation on agricultural products and a study of equipment and methods for mass exposure are underway.

Industry and other organizations. In recent years one or two companies conducted some preliminary work on radiofrequency treatment of insect-infested grain, but no known work is being conducted at the present time. A number of companies are manufacturing and selling light traps for catching insects. Some of these companies have asked for advice and have based trap design on current USDA information.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Light Traps for Vegetable Garden Insects. Three vegetables which were afforded protection in previous experiments, i.e., sweet corn, cucumbers and tomatoes, were planted in isolated plots and subjected to three different lighting conditions as follows: (1) Five black-light (BL) lamps; (2) five green-photo lamps; (3) three green-photo lamps plus two BL lamps. All lamps were rated at 15 watts. Substantial reductions in damage to corn and tomatoes were observed for the most effective lighting treatment as compared with the unlighted checks. For cucumbers, the combination of insecticides to vining time plus lights throughout the season protected the plants from cucumber beetle damage as well as did insecticides applied throughout the season.

Light Traps for Cotton Insects. Field studies involved several species of cotton insect pests, but due to difficulty in obtaining sufficient numbers of pink bollworm moths, laboratory studies were concerned primarily with a stored-products insect, the almond moth.

Laboratory studies in Texas on effects of the frequency of flickering of a light source on its attractiveness to night-flying insects were

conducted in a Y-shaped test tunnel with the almond moth. Eleven flicker rates ranging from 0 to 64 cycles per second (cps) were evaluated at four different light intensity levels for near ultraviolet radiation (365 mu wavelength). Flicker at rates of less than 32 cps were not as effective as steady or nonflickering stimuli of the same intensity and wavelength. High-intensity stimuli became effective attractants at lower flicker rates than low-intensity stimuli. These results indicate that the attractive efficiency of the black-light fluorescent and argon glow lamps commonly used in survey-type insect traps probably would not be improved by operating these lamps at a frequency different from 60 cps.

To check results of laboratory findings, field studies of effects of flicker frequency on lamp attractiveness were conducted. Thirteen flicker rates ranging from 0 to 120 cps (on-off ratio = 1.0) were evaluated by use of a modified argon-lamp survey trap. Data collection was limited by equipment difficulties and low insect populations during the test period. Analysis of collected data of three categories, i.e., weight of insect collection, numbers of bollworm moths and numbers of cabbage looper moths, indicates that none of the flickering sources were as effective as the constant or nonflickering source (0 cps).

Light Traps for Tobacco Insects. Results obtained in North Carolina in 1961 in recapturing marked male tobacco hornworm moths using black-light traps indicated to the cooperating entomologist, Entomology Research Division, ARS, that many hornworm moths in a given area might be captured with a trap density of three traps per square mile. Results show that hornworm moths move considerable distances, but no more than 5 percent traversed a distance of 5.0 miles to traps. Basic information from this study indicated that three light traps per square mile should capture about 90 percent of the male moths and 30 percent of the females in the center of an area 12 miles in diameter. Using a modified basic design new black-light traps were designed, constructed, and installed to provide 324 traps in an area 12 miles in diameter and 42 traps in adjacent areas as checks in 1962. Preliminary data show a reduction in population of moths of both species of hornworms and a lower percentage of mated females in trapped area.

Tobacco growers in Indiana are continuing to voluntarily utilize electric black-light traps for hornworm control with satisfactory results. A light trap for hornworm moths, which was designed using information from previous research, is being manufactured and distributed by a farmer-cooperative organization in that State.

Laboratory studies in Virginia on spectral response of tobacco hornworm moths exposed to different wavelength bands of ultraviolet and visible radiation in the laboratory showed significantly greater responses to bands in the ultraviolet region. Best response was to a band centered

at a wavelength of 3654 Å. Temperature and relative humidity also influenced the response. Greater response was obtained at 75° F. than at 55° F. It was also higher at 80 percent relative humidity than when relative humidity was 60 percent or 40 percent. A greater response was recorded for female moths, which is unexplained since male moths have always constituted the larger percentage of light trap field catches for this species.

Insect Survey Traps. Survey entomologists in nine North Central States continued their use of black-light traps for surveys of insects of economic importance with little change from previous years. Special light traps for the European chafer were developed and used for the first time by Plant Pest Control Division of ARS in their detection surveys. Special inverter power supplies were developed to operate these traps by batteries in remote areas.

Canopy and omnidirectional insect traps have been operated for nine and four years, respectively, near Ames, Iowa, for the detection of European corn borer moths. Corn borer populations were relatively low in 1961, although somewhat more abundant than in 1960. As in the past, the traps with 200-watt incandescent lamps as attractants captured a higher ratio of male to female moths than did those with 15-watt BL fluorescent lamps. The Extension Service operated four ARS-furnished survey traps to obtain information on insect population in areas some distance from Ames. They furnished weekly reports of the catches of 15 species of economic insects to county extension directors and other cooperators.

At the Tidewater (Virginia) Research Station, traps with black-light lamps were more effective than those with incandescent lamps in trapping spotted cucumber beetles in the vicinity of peanut fields that had become seriously infested by the larval stage of this insect. Argon glow lamps were not very attractive to this insect. Data from the limited number of traps used to date do not indicate that a satisfactory degree of control of the spotted cucumber beetles can be obtained. Limited studies will continue.

Light Trap Components and Design. Trials were continued in Indiana to determine the effects of funnel size, lamp wattage, lamp shape, placement of lamp with respect to funnel, fans and trap elevations on the catches obtained in insect traps. Trap effectiveness was evaluated both on the basis of the total numbers of insects collected and on the variety of orders and species of economic importance included in the collections. Further field work will be necessary before definite conclusions can be drawn.

At Chatham, Virginia, the vertical lamp position was found to be more effective in attracting tobacco hornworm moths. Data for the past three years indicate that lamps should be placed vertically on traps for best results in capturing tobacco hornworm moths.

The effect of lamp mounting position was also studied using 32-watt circline BL lamps in modified black-light survey traps. One lamp was mounted within the trap funnel in such a manner that all radiation was emitted into a 180° solid angle above the plane of the top of the funnel. The other lamp was mounted slightly above the trap funnel, permitting radiation to strike the ground and vegetative matter in the vicinity of the trap. The trap with the ground and surrounding plants shielded from the light caught significantly larger numbers of insects in general.

Insect Control in Grain. Studies in prior years have established that brief exposures to radiofrequency (r-f) electric fields can kill insects in infested grain without damaging the germination of the grain. Egg and larval stages have been more resistant to such control, but treatments of about 5 seconds, which produce grain temperatures in the range from 140° to 150° F., have been sufficient to kill all developmental stages of most insects tried in laboratory tests. Results show that somewhat longer exposures are required to obtain complete control of some dermestid larvae. Treatments using high electric field intensities were more efficient than low intensities in killing dermestid larvae and granary weevil. Preliminary work indicated that r-f treatments providing insect control also may reduce activity of grain storage fungi. Studies of the physiological effects of r-f treatment on American roaches using chemical analyses have revealed differences between the nerve tissues of untreated insects and those receiving sublethal exposure.

Basic Studies of Radiation Treatment for Grain. The water sorption of grain sorghum seed was increased by radiofrequency treatment and germination and field emergence were accelerated. Genetic observations on grain sorghum revealed no increase in the number of mutants due to treatment. In Washington, information was obtained on the effect of glow-discharge treatment on the emergence of winter wheat. Effects on coleoptile length were studied, since prior research has established that seedling emergence and vigor are directly related to the length of the coleoptile. Greenhouse tests showed no increase in coleoptile length due to irradiation; however, some decrease in plant height with no decrease in coleoptile length was observed. Since breeders are interested in developing varieties with shorter straw, field trials to study emergence, plant height and yield are underway.

Radiation Treatment of Legume and Grass Seed. Radiofrequency treatment has been effective in converting hard seed in alfalfa, red clover, and ladino clover to immediately germinable seed and effects of treatment have remained in alfalfa seed stored for two years. Treatment is more effective when seed moisture content is low. Water-sorption measurements have shown that reductions in hard-seed percentage are accompanied by an increase in the capacity of seeds to take up water. Basic experiments on Washington-grown Ranger and Vernal alfalfa seed with high percentages of hard seed have shown that glow-discharge radiation is quite effective

in reducing the hard-seed percentage and correspondingly increasing the number of immediately germinable seeds. Glow-discharge treatment of Narragansett alfalfa seed increased germination 30 percent by lowering the percentage of hard seeds, and produced a significant increase in rate of emergence from sand in greenhouse tests conducted at Lincoln, Nebraska. The hard-seed percentage in golden annual sweetclover was also significantly lowered by treating very dry seed. Germination of Newport bluegrass and camels-thorn was also increased by glow-discharge treatment.

Glow Discharge Plasma Treatment for Cotton and Cottonseed. Results of field tests at Stoneville, Mississippi, showed that the emergence of acid-delinted cotton seed by the fifth day after planting was increased nearly twelvefold by glow-discharge treatment prior to planting, the count being 1,175 as compared with 99. Emergence of treated gin-run seed on the fifth day was 289 as compared to 179 for untreated seed, and on machine-delinted seed the corresponding emergence counts were 807 and 823. New Mexico field tests showed no improvement in emergence. Greenhouse tests in Arizona revealed that glow-discharge treatment produced a beneficial effect on germination of Pima S-1 cottonseed.

Empire WR cottonseed (gin run, mechanically delinted and acid delinted) when treated in an electric glow discharge was found to germinate earlier and have better seedling development than untreated seed. The seeds were germinated on paper toweling in a seed germinator which was operated at 20° C. for 16 hours and 30° C. for 8 hours each day. Germination tests on Acala 1517D cottonseed showed no improvement due to treatment.

Investigations of the effect of low-intensity, 20 milliamperes (ma.), electric glow-discharge treatment of cotton fiber revealed that the dyeing properties of cotton fiber were improved. Viscosity tests on cotton fiber treated at 80 ma. showed an increase in fluidity when dissolved in a cellulose solvent. Microscopic examinations revealed that treatment of 30 ma. and above damaged the cotton-fiber cell wall.

Cotton yarn was subjected to electric glow-discharge treatments at 20 and 40 ma. for approximately 30 seconds in air, oxygen, and helium. Breaking tests showed all treated yarns to be stronger than the untreated yarn. The yarns treated in air and oxygen were stronger than the yarn treated in helium.

Glow Discharge Plasma Treatment of Soybeans. Preliminary tests with soybeans indicate that different varieties respond differently to the glow-discharge treatment; however, germination and seedling growth from treated Ogden soybeans were both superior to the untreated control. Increasing the current in the glow discharge caused an increase in the amount of materials diffused from soybeans immersed in water. An increase in nitrogenous materials in the solute was noted as treatment

intensity increased when whole beans were soaked in water; however, no difference in soluble nitrogen from treated and untreated soybean meal was noted. No difference in amino nitrogen was noted in treated and untreated soybean meal. Exposure of soybeans to a glow discharge increased their respiration rate.

Radiation Treatment of Vegetable Seeds and Dry Beans. Germination of okra seed was increased from 22 percent to 59 percent by reducing the number of hard seeds with radiofrequency radiation. Further data have been obtained on the radiofrequency dielectric properties of vegetable seeds at Lincoln, Nebraska. A study of the effects of glow-discharge radiation on dry beans at Pullman, Washington, has shown a small increase in moisture absorption, but no significant decrease in the time required for cooking. A reduction in the hard-seed percentage of beans due to the irradiation was observed.

Glow Discharge Plasma Treatment of Rice. Based on the data from cooking tests of rice treated at 0 and 50 ma., 2 mm Hg pressure and times from 5 to 140 minutes, and on the acceptability of the cooked samples, the following observations were made by personnel of the ARS Southern Utilization Research and Development Laboratory, New Orleans, Louisiana:

(1) The grains of rice from all treated samples, when cooked, were much larger and more translucent than those of the control. (2) Cooking times do not correlate well with the hydration data. (3) Cooking times of irradiated samples were not significantly different from those of the vacuum-treated controls. (4) The benefits of the treatments (either vacuum or irradiated) were appreciable only when the rice was presoaked prior to cooking. Very limited observations indicate that 15 minutes is the minimum presoak period required. (5) At higher intensities of treatment which browned the rice, flavor changes were noted in the cooked samples. (6) Treated Zenith was much more pasty and cohesive after cooking than was the untreated control. (7) It was found that rice under vacuum treated with heat had hydration characteristics comparable with the rice receiving the plasma treatment. Formation of free fatty acids during storage was inhibited in treated samples and the oil from treated rice was less soluble than oil from untreated rice.

Electrostatic Seed Separation. Present seed separation practices are based upon such physical properties of seed as density, size, length, or surface texture. When two seeds are enough different in one or more of these properties, they can be separated without difficulty. However, some seeds are similar in these characteristics and cannot be separated readily with conventional methods. There is some evidence that various seed types react differently in electrical fields, so equipment designed to exploit electrical properties of seeds may provide another means of separation. At Corvallis, Oregon, evaluation of an electrostatic seed separator under development was continued, and a new approach was tried which combined electrostatic and electromagnetic principles in producing

a "cyclotron" effect to help separate given seeds. In an evaluation of the present electrostatic unit, several problem seed lots were found to respond nicely to this method of separation. Most of the separations were obtained by pinning the contaminants to the belt, thus providing a lift fraction that was relatively clean. Pinned in this way, were chevril, trash, cranesbill, and hulled Bermuda grass. In each case, the surface texture or shape of the contaminant is somewhat different from that of the crop in which it occurs. This shape-texture effect has been observed in earlier trials and appears related to how well a seed retains an electrical charge. One of the most efficient separations was the removal of cranesbill from turnip where the yield was 96 percent, free of cranesbill. In this case, the electrostatic unit apparently sensed a texture difference too small to permit separation by ordinary texture means. A different approach to electrical separation consists of charging seeds electrostatically and dropping them through a strong electromagnetic field where seed deflection can then take place. In some respects, this technique is similar to that used by cyclotrons to accelerate charged particles. The seed-charging assembly used one grounded plate and one plate attached to a 20,000 volt source. The electromagnet was built up to provide a flux density of 3,000 gauss. As seeds slide down the inclined plate, they receive a charge and then drop between the poles of an electromagnet. When the charged seeds fall through the magnetic field, they are deflected from their normal vertical drop. The amount of the deflection depends upon seed charge, field strength, and seed velocity through the field. Large enough values for these factors will provide a range of deflected seed paths (assuming that different seeds carry different amounts of charge as they enter the magnetic field). The variation in initial seed charge will stem from any basic differences in electrical properties of seeds to be separated. Preliminary trials with the electrostatic-electromagnetic apparatus showed that no seeds were deflected enough to permit separation. This means that at least one of the influential factors (seed charge, field strength, or seed velocity) must be increased before this separating method can be evaluated. Once physical conditions are provided this can cause any given seed to be deflected from a vertical fall. A difference in seed charge can be detected and utilized according to its influence on deflection paths.

Other problem seed mixtures that have been handled with varying results by this machine include the removal of rocks, stems, and manure chips from buffalo grass resulting in 85 percent purity and 80 percent yield. Morning-glory and asparagus seed responded 80 percent yield; 95 percent to 100 percent purity. Newport bluegrass with shrivelled and broken wild garlic responded with a 100 percent removal of the wild garlic and only a 5 percent bluegrass removal. In a special test conducted in cooperation with Stoneville Cotton Ginning Laboratory, a lot of cotton seed with a germination of 39.5 percent was separated into two fractions with germinations of 3.5 percent and 51 percent respectively.

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AREA 12, ELECTRIC EQUIPMENT FOR FARM LABOR REDUCTION

Problem. American agriculture produces about 600 million tons of crop and animal products each year. This is more than five times the weight of the total annual steel production in the United States. Most of these products are handled several times, which means a tremendous task of moving material. Development of equipment to decrease labor of livestock chores has been far less rapid than development of field equipment. For example, the production per man-hour for all crops increased nearly 400 percent in the last 50 years while the increase for poultry was only about 250 percent, for milk cows about 150 percent, and beef cattle less than 50 percent. The amount of working time spent on livestock production (estimated to be 3,833 million man-hours per year in 1961) now is 40 percent of the entire farm labor requirement. Equipment to substitute electric energy or tractor power for hand labor for many farmstead operations is now on the market but research is needed to provide flexibility of use in existing buildings and to permit automatic control as well as to extend mechanization to other operations. Because livestock chore equipment may be needed 365 days per year, it should pay for itself more quickly than field equipment which may be used only a few days per year.

USDA PROGRAM

The Department has a continuing long-term program with engineers working cooperatively with state experiment stations, USDA entomologists and other scientists on basic and applied research. Equipment and control for automatic feeding of livestock and poultry is under development in Washington and Illinois State Experiment Stations. Work on performance characteristics of upright-silo unloaders is in cooperation with the Minnesota State Experiment Station. Work on equipment for handling bees and honey is in cooperation with the Apiculture Branch, Entomology Research Division, and the Arizona and Wisconsin State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 6.6 professional man-years; of this number 2.0 are devoted to bee equipment, 4.1 to equipment for livestock and poultry, and 0.5 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 14.2 professional man-years engaged in this field divided into the following sub-areas: dairy equipment 4.1, beef equipment 1.3, poultry equipment 0.7, swine 0.4, automatic electric controls 1.5, performance characteristics of electric equipment 1.6, materials handling systems 4.1, and other 0.5

man-years. Part of this research is cooperative with the USDA. Investigations to analyze and to develop and test equipment for systems to mechanically feed and service beef and dairy cattle, swine, and poultry are in progress. These studies involve the design and installation of automatic feeding systems for blending mixed rations and roughages according to various levels of production and the removal of waste materials. Included also are investigations to determine the necessary specifications and functional requirements for improvements in a mechanical system for removal of chopped hay and silage from storage and its transport for animal feeding. These studies are a part of cooperative Regional projects NE-13, Studies of the physical properties, behavior, and forms of forage as related to engineering application and NC-48, Development of materials handling systems for North Central farms. Research is underway to determine the operating characteristics of various conveying systems and forage and silage unloading devices and to determine the functional requirements and design of automatic controls for an integrated system for livestock feeding operations. The primary objective of these studies is to arrive at suitable methods and equipment to reduce the labor now required and thus reduce unit cost of production. Some similar work on equipment for swine, poultry, sheep, bees, and milk equipment is conducted in various states.

Industry and other organizations. Most manufacturers of "on-the-farm" equipment for livestock and poultry are engaged in testing the performance of their product design and developing improved products. Some are also investigating farm application of products designed for other uses and a lesser number are developing new equipment or methods to meet specific problems in the livestock and poultry industry on farms. Feed grinders suitable for hard corn in Kansas, for example, are not necessarily satisfactory for soft corn in Minnesota. Research is often conducted on a cooperative basis with electric utilities and with State Experiment Stations to save costs and to obtain nationwide results in testing equipment under a variety of conditions and crops. Industry maintains close contact with USDA research for information on functional requirements and performance characteristics for electric motors, equipment and controls; for example, the motor and control requirements for silo unloaders. The estimated annual industry expenditures for research on items specifically for "on-farm" use are believed to be approximately 10 man-years on poultry equipment, 10 on beef equipment, 10-15 on dairy equipment, 5-10 on swine and less than 5 on sheep equipment.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Cattle Feeding Equipment. In Illinois the control system of the automatic beef feeding system has been modified this year by provision for adding high moisture shelled corn to the ration. Silage, high moisture shelled corn, and a ground feed concentrate can be blended to form either of two rations for automatic feeding, each to one of two lots. The winch control relays for the silo unloader have been modified to give fast-make, slow-break, contact action. This prevents the unloader from

"hunting." The rate of discharge of silage from the silo by the automatically controlled silo unloader is controllable from 60 to 170 pounds per minute with a variation of 5-10 pounds/minute in 300 lb. samples. A variable orifice, constant speed auger meter tested in the high-moisture shelled corn storage tank was unsatisfactory. The soft shelled corn was crushed by the auger; the crushed corn impeded the flow of grain through the metering orifice and resulted in an erratic flow of material from the storage bin.

In Washington a low power electrically driven silage cutter unit for use in unloading trench silos has been developed and successfully tested in both chopped and unchopped grass and pea vine silage. The cutter uses two 12 or 16 inch counter-rotating augers 25 inches long. The cutter operates perpendicular to the silage face traversing from left to right and top to bottom in successive cuts. The cutter unit requires two horsepower to remove four to six hundred pounds of silage per minute. The cutter is the first step in the development of an automatic trench silo unloader. A public patent will be sought to protect this development.

In Minnesota the silo on the premises of the Agricultural Engineering Farm was used for comparing several motors on one make of unloader. These tests pointed up the difficulty of adequately protecting against burn-outs in motors designed for high torque and short duty cycle. The use of ammeters along with built-in motor protectors and current-sensitive relays appears to be most suitable. The tests were a factor considered by one manufacturer in deciding to redesign his motor for this application.

One reason farmers purchase silo unloaders is to save time and labor. This objective has not been entirely attained. Lowering of some types is still done manually which requires the presence of the operator. Two silos were equipped with small gearhead motors belted to the winch of each unloader. Mechanical lowering resulted in a very uniform load on the unloader. Adjustment of the pulley drive ratio had to be made to compensate for the decreasing diameter of the winch drum and cable. Other controls are necessary to prevent stalling.

Apiary Equipment. In Wisconsin a honey strainer with 188 sq. in. of nylon cloth straining surface was found to have twice the capacity (1000 pounds) before cleaning was required when uncapping method was changed from perforating rollers to vibrating knife. This unit is more easily cleaned and requires less cleaning time than other units used at this station. New units ready for use have 350 sq. in. of straining surface area and require only removal of the cloth supporting frame for cleaning, the containing body remaining in the line. Parallel units provide continuous flow operation.

Comparative temperatures indicate that a satisfactory sequence of conditioning has been determined so that honey temperature can be controlled

at desired levels through the strainer, pasteurizer, and cooler without injury to the honey. Temperature difference between the honey and water must be a minimum of 20 degrees F. to obtain satisfactory heat transfer in the heating and cooling process.

Attempts to extract honey directly from the frames within super bodies in a 50-frame radial extractor were unsatisfactory. Comb breakage in square supers ran from 50 to 60 percent and in standard supers ranged from 30 to 40 percent. Breakage was due to the angularity of the comb surface to the axis of rotation producing high stress in the comb from unequal weight distribution during extracting.

In Arizona plastic comb sections with several different cell shapes and sizes were made with high density polyethylene. Test results which will indicate the acceptance or rejection of the combs by bees are not available at this time. It was found that bees would accept and use an experimental aluminum foundation if crowded conditions required but showed preference for wax foundation. Carbon dioxide which acts as an anesthetic to bees was checked for the possibility of use in removing bees from filled honey supers. Results were entirely negative.

A portable hive scale for quick measurement of honey production has been built utilizing a tension weight measuring device. The tension measuring unit is more reliable than the previous compression measuring unit.

Dead bee traps are used to measure the mortality among colonies of bees. Traps covered with three-mesh per inch wire are 96.6% effective, whereas, one- to two-mesh per inch wire is 85.8% effective.

The frame for the portable bee colony shade has been re-designed and simplified. This revision has performed very well in tests.

Several materials were investigated for covering colonies to protect the bees from insecticides. Wet burlap was the most effective. Colony temperatures under wet burlap were 92 degrees F., colony temperatures under dry burlap were 98 degrees F., and the check colony was 95 degrees F. Colonies can be held under wet burlap for two days without excessive loss of bees among the colonies. Black polyethylene film will protect bee colonies from direct application of insecticides; however, in a period of four hours, the colony temperature may be expected to rise two to seven degrees. Due to buildup of heat under the plastic, it was not possible to keep the colonies covered after 11:00 a.m. without loss due to overheating. Sprinkling water on or near the hives will enable the bees to keep the hives as cool when covered with black polyethylene film in the sun as if the hives so covered were under a shade.

Beehive temperatures will lag the outside temperature change by one to three hours. The makeup of the hive (brood and colony storage) influences the rate of temperature change.

Basic studies were conducted in which colonies were held in controlled ambient temperatures from 50° to 120° F. to determine temperature changes in the hive and the colonies' need for water. At approximately 90° F., the colony temperature control changes from heating to cooling the hive. At 90° F. bees had used before daylight the water that they had collected the day before; at 100° F. the bees clustered in front two to three hours after sunset. A hive overheated because of the lack of water will cool in two hours after water is available for the bees. Bees can control hive temperature with sugar solution up to 50 percent but the temperature pattern is different than for water.

Hog Equipment. Cooperative work is currently being carried out with the Agricultural Engineering and Animal Science Departments of the Illinois Experiment Station on automatic feeding of hogs at definite time intervals and varying amounts of feed in comparison with self-feeding. Two new experimental dump tube feeders, electrically driven and time controlled, are available for these studies.

Poultry Equipment. In Illinois a medium pressure (about 10 p.s.i.) ground feed conveying system has been under development. Although initial installations have been on poultry farms, the system is applicable to livestock using ground feed.

One change has been made in the conveying system on a cooperating farm during the past year. The rapid wearing of the diverter valve liners is still a problem. Feed hits the liner after it makes the 30-degree turn at the diverter valve. The valve liner wears out quickly in a small area. A 30-degree branch line diverter valve has been replaced by a 45-degree valve. The 45-degree turn will distribute wear more evenly over the liner.

A new auger-feed injector has been developed to replace the rotary air lock feeder valve previously used for getting the feed into the air line. The first successful model consisted of a 2-inch half-pitch horizontal auger force-feeding a vertical auger of the same type and size. Above the vertical auger was a tapered section of a cone that serves as the air lock. It acted as a one-way valve permitting the feed to move upward easily through the flared section with very little force required. At the same time, it prevented the escape of air back through the injector. The feed passed from the tapered section into a mixing chamber where it was picked up by the air and moved down the pipeline.

The two-auger feed injector has been modified to eliminate the vertical auger. The horizontal auger forces feed directly into a tapered 90-degree flared elbow. The feed is moving in a vertical direction when it enters the mixing chamber. This injector is simpler than the two-auger injector. The single-auger injector has been thoroughly tested in the laboratory and is ready for field testing.

Basic studies of the pressure drop for a range of air flow and feed rates through elbows in a 1-inch pipeline was limited to elbows of 6-, 9-, and 12-inch radii of curvature. Two 6-inch elbows, one of which was flattened $1/4$ inch; three 9-inch elbows, one of which was flattened $1/4$ inch, and one flattened $1/8$ inch; and two 12-inch elbows, one flattened $1/4$ inch, were investigated. The $1/4$ -inch flattened elbows generally had less pressure drop than either the round or $1/8$ -inch flattened elbows of the same radius. The 9-inch radius elbow again showed less pressure drop than either the 6- or 12-inch.

Pressure drops in two 50-foot straight sections of pipe were studied and compared to an equal length of pipe with an elbow included. The equivalent length of straight pipe for an elbow in the pipeline varied from about 10 to 30 feet depending on the amount of air and feed being conveyed. The equivalent length of pipe for an elbow was maximum at a feed-air ratio of 15:1 and decreased as either more or less feed was conveyed.

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AREA 13, ELECTRIC AND SOLAR EQUIPMENT FOR ENVIRONMENTAL CONTROL

Problem. Research has shown that temperature, light, space, and other environmental factors affect the growth, health, fertility, production, and feed consumption of farm animals. Thus, savings in feed, reduced losses from disease and exposure, and decreased costs of production may justify many environmental improvements. Special, controlled environments are necessary for the proper conditioning of crops like tobacco, sweet potatoes, grain and peanuts; and are extremely effective in maintaining the quality of stored fruits and vegetables. Current scientific and economic developments indicate that production of vegetables and flowers may require complete control of soil, light, and atmospheric conditions. Engineering problems associated with the application of light to plants have increased in recent years with the need for growth rooms for research and commercial use of light for growing crops. The normal season during which turkey breeder hens produce fertile eggs is quite short, with resultant high egg cost. Engineering the quality and quantity of light to increase the season for hatchable eggs is a current activity. Conditioning and safe storage of high moisture grain are major problems for a great many farmers. Use of solar heat to aid in drying offers potential economy in this operation. The lack of available electric energy in remote areas of farms has limited the use of electric devices. Conversion of solar to electric energy at the site for adapting new and more efficient thermoelectric devices to farm application may eventually eliminate this energy shortage.

USDA PROGRAM

A new program at Beltsville has been established whereby engineers from the Agricultural Engineering Division cooperate with the Crops Division on basic studies of light and thermal environment and their relation to plants in growth chambers. A continuing basic and applied program is underway in Kansas in cooperation with the Kansas State University on solar energy collection and storage for grain drying and for supplementing heat energy to air-source heat pumps for house heating. Solar energy collection and storage for direct house heating is also underway at Athens, Georgia, in cooperation with the Georgia Experiment Station. Research on equipment for basic and applied studies involving light and thermal environment for poultry is underway at Beltsville in cooperation with the Poultry Branch, Animal Husbandry Research Division. At Athens, Georgia, basic studies are underway involving diurnal variations of temperature, humidity, and air velocity effects on growing broilers in cooperation with the Poultry and Agricultural Engineering Departments, University of Georgia. Basic and applied studies on the

use of heat pumps to modify thermal environment for hog production were recently started at Holland, Virginia, in cooperation with the Virginia Agricultural Experiment Station. Basic and applied research on tobacco curing at Oxford and Raleigh, North Carolina, in cooperation with the North Carolina Experiment Station and Crops Research Division was discontinued June 30, 1961.

The Federal scientific effort devoted to research in this area totals 6.3 professional man-years; of this number 1.2 is devoted to plant environment equipment; 1.4 to house heating and cooling equipment; 2.2 to poultry environment equipment; 0.2 to swine environment equipment; 0.8 to solar grain drying and conditioning; and 0.5 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported an estimated total of 9.6 professional man-years of research on heating, cooling, ventilating, and air-conditioning equipment for modification of environment for live-stock, crops and growing plants, divided among subheadings as follows: dwellings, 0.6; dairy cattle, swine, and poultry, 4.3; stored crops and plants, 0.4; engineering phases of application of light to animals and poultry, 1.6; solar radiation as a heat source, 1.4; and thermoelectric applications, 0.5.

Industry research effort on electrical facilities and fixtures specifically for installation in farm buildings is only a very minor portion of the overall industry program, the major portion being for industrial and other non-farm structures. Functional requirements and design criteria resulting from State and Federal research are largely used by industry for guidance in farm application of equipment for environmental control. Estimated animal research expenditures are equivalent to less than 5 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Plant Environmental Equipment. In Washington, equipment for basic studies on the relation of carbon dioxide and light to their effects on plants is being operated in three air-supported, plastic greenhouses. Three identical 14 x 23-foot air-supported, plastic greenhouses have been constructed, one to serve as a control (no added carbon dioxide) and two in which the carbon dioxide concentration can be controlled. Through the use of one such greenhouse provided with a complete air recirculation system, it was believed that carbon dioxide losses from the building could be minimized and more efficient use of the added carbon dioxide obtained. A system for measuring and controlling the carbon dioxide levels has been designed and installed. The major components of this system are an infrared gas analyzer and a strip-chart recorder-controller. The system allows the carbon dioxide concentration in all three greenhouses and the outside atmosphere to be measured,

recorded and the carbon dioxide concentration in two houses to be controlled. Total radiation readings are taken by the use of a pyrheliometer. The present source of carbon dioxide is bottled gas.

House Heating and Cooling Equipment. In Kansas a comparison of a solar-supplemented and a conventional air-to-air type heat pump has been accomplished for the first essentially complete (93 percent of total degree days) heating season from November 1960 to May 1961. The solar-supplemented system consists of 800 square feet of vertical south-facing solar collectors; an underground rock heat storage with 50 cubic yards of limestone rock passing a $2\frac{1}{2}$ -inch screen and retained on a 1-inch screen; associated electrical and electronic controls; and an air-to-air heat pump. The solar supplemented heat pump system operated at an average performance factor 13.5 percent higher than the conventional heat pump system with maximum and minimum increases of 30 and 2 percent respectively.

Criteria on automatic controls to maximize performance are being analyzed but the functional requirements for controls to maximize performance are not yet fully developed. Selection and integration of control elements into an automatic system to economically accomplish the above objective must necessarily follow this functional clarification.

A selected area of the ground surface was insulated above the storage system and is being compared to a similar uninsulated section. A partial summary of data taken in December 1961 showed that the average rate of heat flow from the ground was greater by a factor of 2 to $2\frac{1}{2}$ for the uninsulated as compared to the insulated section. The open-plenum section of the storage system was insulated during initial construction with two inches of cork placed on top of the rock storage and then covered with about three feet of earth. The data indicate that the heat flow transducer should be placed at the storage level to adequately indicate heat exchange between storage and earth.

A significant contribution of the solar supplemented system has been the reduction of defrosting requirements. Data show an overall increase, due to solar supplementation, of 65 to 70 percent (55 to 60 percent 1959-60) in the heat pump operating hours before defrosting was required.

Modified types of collector cover construction appear to be durable and thus far have given satisfactory service. Observations indicate that the design using horizontal bowed wooden braces (rather than both horizontal and vertical braces) provides a better method of holding the nylon reinforced film plastic cover in tension and away from the metal absorber surface during windy or changeable temperature weather.

In cooperation with the Kansas Committee on the Relationship of Electricity to Agriculture, technical consultation, provision of equipment,

and instrumentation and assistance are being rendered in a research project using a solar supplemented preheater with an electric water heater. A photoelectric switch is used to control a water pump for the purpose of collecting solar heat energy. Temperature, B.t.u., heat, and electric energy meters and pyrhelimeter records are providing data to analyze the performance of the system.

In Georgia, first year studies of solar energy collection for supplemental heating of rural dwellings indicated that it was not feasible. A heat storage was then incorporated in the system for the 1960-61 tests. The savings with the heat storage in operation were unsatisfactory because: (1) Resistance to air flow through the crushed rock, used for heat storage, was greater than estimated, reducing the rate of air flow and the collector efficiency and (2) too great an imbalance was allowed in the heat storage capacity and collector output for long periods of cloudy weather.

Crushed rock samples were screened to various sizes and resistance-to-air-flow tests were run to provide information needed in sizing the blower and motor. Tests indicated that finned collector plates gave about 30 percent greater efficiency than unfinned plates. These improvements have been incorporated in a new combination solar collector and heat storage and heating tests are underway. (For additional report on rural dwellings see area 8.)

Poultry Environmental Equipment. Beltsville White turkeys were subjected to gradually increased day-length from maturity through one season of lay under normal and controlled environments. These basic studies in cooperation with the Poultry Branch, Animal Husbandry Research Division, are a continuation of length of photoperiod and abrupt versus gradual change in photoperiod. Starting with a natural day-length of about 9 hours in December, birds were subjected to 11, 13, and 15 hours. Day-length was increased for each group approximately 15 minutes at 2-week intervals until an 18-hour day-length was reached. There were no important differences in fertility and hatchability. Egg production was slightly more in the 13-hour group than the 11-hour group and also slightly more in the 15-hour group than in the 13-hour group. The average length of effective breeding season for all pens was 28 weeks.

Approximately one-half of each group was housed in conventional range houses with incandescent lamps supplementing natural daylight for day-length control. The remainder of the birds were maintained in a controlled temperature and relative humidity room ($65^{\circ} \pm 5^{\circ}$, and 70% relative humidity) with daylight excluded and light supplied by incandescent lamps. During the season of test the birds in conventional houses were subjected periodically to subfreezing temperatures and to moderate heat stress at the latter portion of the experiment. The 11-hour group in outside environment produced less eggs than comparable

inside groups. However, the longer day-length groups showed little difference in performance due to environment. An article on this work has been accepted by the Poultry Science Journal for publication.

An electromechanical system for recording the time at which individual fowls lay eggs was assembled for trial use. A row of metal fingers (1-1/4 in. long spaced 1-1/2 in. apart) is mounted on a shaft over the egg trough of a battery cage. Each time an egg rolls under the fingers a mercury switch on the shaft revolves with the fingers and closes the circuit to a recording pen of an operational recorder. The marked operational chart then provides a record of the time a hen lays her eggs. One recorder serves 20 cages. In Georgia, a small facility for basic investigation of the effects of air movement (0.8) on growing chickens was designed, constructed, and placed in operation in Spring of 1960. Six trials have been conducted in the air movement facility, using broiler-type chickens approximately six to nine weeks of age. Five constant air velocities, ranging from 15 to 500 feet per minute, were maintained during each 2-week growth period. Air temperatures and humidities were the same for each velocity and were programmed to simulate a typical hot day cycle. As air velocity increased, growth rates and feed efficiencies increased and water consumption decreased.

Swine Environmental Equipment. In cooperation with the Virginia Agricultural Experiment Station a study was initiated utilizing heat pumps for determining the optimum equipment requirements for efficient methods of producing hogs from weaning to market weight. The facilities include a 24 x 60 ft. temperature-controlled building and a half-open building that have identical concrete floors and pen areas; and an open feed lot for a check. Studies on the space per animal are being made in the pens on the concrete floors. Carcass quality analyses, as related to the production facilities, are also being determined.

This project involves one summertime and one wintertime testing period per year. Each period requires 7 groups of 15 animals, 3 in each of the buildings and 1 in the open feed lot. The animals subjected to the first summertime testing used primarily as a check out period for equipment and instrumentation were slaughtered and subjected to carcass analyses at the Virginia Agricultural Experiment Station Animal Processing Laboratory. Data are being statistically analyzed. A wintertime testing period is currently in process.

Several tests will be required to confirm results that may be notable.

An automatic feeding system has been designed and will be installed prior to the 1962 summertime testing period. A lagoon waste disposal system for the facility is in use.

Basic studies on the effects of variously charged air particles on hogs were continued at Davis, California, in cooperation with the State Station. Durocs, in groups of four, were subjected to one- or two-week periods of either normal, excess positive or excess negative ions. At 90° F. weight gains and feed conversions have been quite inconsistent except that, in all cases, one of the ion treatments has resulted in improved gain and conversion. More data are required and "ion houses" have been constructed for this so that pigs can be subjected to the three conditions simultaneously. Ozone testing equipment was designed and built and is now being used to determine ozone concentrations.

Efforts to develop cooling indices from records of power used by air-conditioning units, produced quite good correlations. Several years' records were collected at Davis, California, on the amount of power used by air-conditioning units on turkey pens (housing caged birds) and swine houses used in other research. These records were analyzed at Columbia, Missouri. The indices used so far include cooling degree-days based on the daily mean temperature above 60° F. and on the Temperature Humidity Index above the value of 60. Correlations of these indices were quite good for the data analyzed to date. It is possible that use of computer facilities will develop an even better cooling index, and also allow pooling of data from the various units to provide prediction of operating costs beyond the limitations of the actual air-conditioning units for which data were recorded.

Solar Grain Drying and Conditioning. In Kansas, a plastic solar collector to heat outdoor air was compared with natural air alone for fall high-moisture grain drying "in storage." Research in 1960 was expanded from experimental scale bins to 1000-bushel milo storages. Similar results to those obtained in previous year small-scale tests were obtained. A 45 percent reduction in the blower energy when using solar heat supplementation, as compared to natural air drying, was found in 1960. The following year, solar supplemented drying was compared with conventional natural air for sorghum grain drying for higher moisture contents (25 percent) than previously investigated. The solar supplementation provided successful drying without other supplemental heating equipment. Concurrent drying with natural air required fuel-fired supplemental heat to avoid grain spoilage. Blower energy required with solar supplementation was approximately 60 percent of that in which natural air alone was used and averaged 0.1 kw.-hr. per bushel per percent moisture removed to safe storage level of the grain. A partially air-supported ground surface solar absorber (fabricated from plastic film) was used for solar heat collection. Additional designs of heat-sealed air-inflated or supported film collectors have been fabricated for testing for possible easy portability, facility in use, and compact storage.

Tobacco Curing. In cooperation with the North Carolina and Tennessee Agricultural Experiment Stations investigations were conducted relating methods and equipment to the curing of bright-leaf, dark-fired, and air-cured tobaccos. This work was terminated during 1961.

In North Carolina the adaptation of design (incorporating functional features) and size scaling up of equipment used in pilot-plant bulk curing of bright-leaf tobacco was completed. A bulk-curing barn built by a commercial company working in cooperation with the Agricultural Engineering Department and Agricultural Research Service was sized to replace a normal 20 x 20 ft. barn. A farm test of bulk curing was made in Robeson County, North Carolina. The same features of air recirculation, thermostatic control, and racking were employed as those of the pilot curing unit. A total of nearly 10,000 lbs. of cured tobacco averaged \$65.40/cwt, at about \$5.00/cwt above average market prices for comparable grades. Results indicated that bulk curing was practical as a farm operation.

To determine practical levels of density in the concentration of product for bulk curing, the effect of two levels of density (100 and 120 lbs. green wt. per bale) on the curability of bulk tobacco was evaluated by comparing with conventionally cured leaf. Tobacco from both densities was similar in appearance and received identical government grades. Bulk-cured tobacco averaged slightly higher than conventionally cured tobacco, based on government support prices.

Laboratory investigations concerning the electrical properties of tobacco were continued. The dielectric constant (K) of green leaves decreased semi-logarithmically with frequency in the range 1KC to 1MC, while for cured leaves it showed a log-log variation. For cured leaves K increased sixfold for a temperature increase from 77° F. to 150° F. The dielectric constant was higher for Dixie Bright 101 than for Hicks or Coker 139 varieties.

Investigations of the fluorescence spectra of intact leaves showed that gross maturity differences in turgid leaves can be detected at 470 mu. The fluorescence spectra of leaf compounds were located within the spectra of intact cured leaves. The cured leaf was characterized by a prominent fluorescence band at 525 mu, while the turgid leaf had two bands, a prominent band at 465 mu and a minor band at 525 mu.

In Tennessee supplemental heat was added to a barn of 14.5 cwt and compared with air curing of an identical size barn containing 8.5 cwt of burley tobacco. An increase in barn curing capacity for 1960 of approximately 70 percent was obtained by using supplemental heat. Though a higher market price was received for the supplementary heated

air-cured tobacco, after deducting the cost of fuel, approximately \$4 less net per cwt was realized when compared with the \$64.49/cwt price received for the air-cured product. Decisions as to whether to consider heat supplementation must therefore weigh these economic implications and considerations and be related by the farmer to the size of crop and the barns available for curing.

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AREA 14, FARM ELECTRIC SERVICE AND RESEARCH INSTRUMENTATION

Problem. Farms east of the 100th meridian used twice as much electricity in 1959 as they did in 1950 and three times as much as they used in 1945. Increased use has forced many farmers to rewire or partially rewire their farmsteads at considerable cost. Overloading of installed wiring results in poor equipment performance, energy losses in the wiring, and creates a fire hazard. Transformers burn out or must be replaced due to overloading. There has been no good method of predicting when a transformer should be replaced and many power suppliers are faced with the problem of finding a simple, effective one. These problems are expected to become increasingly acute as farmers install additional electrical equipment such as house heating units, air-conditioning, milk coolers, motors for feed processing and distribution, and irrigation pumps.

Today's technology in farming, as well as research, requires accurate instruments for measuring or monitoring processes such as grain and forage drying and plant and animal environment. Current agricultural research is especially dependent upon accurate instrumentation; some problems require completely new kinds of instruments. Studies are necessary to determine the accuracy and practicability of instruments for many kinds of agricultural measurements.

USDA PROGRAM

The Department has a program involving agricultural and electrical engineers to develop an improved method of estimating the maximum electrical demands of farms. This program is in cooperation with the Iowa Experiment Station, the Rural Electrification Administration, and power suppliers in Iowa, Montana, Minnesota, North Dakota, Wisconsin, Kentucky, and Alabama. Data on energy consumption and electric equipment used on farmsteads are analyzed to predict electric demands by farms situated under similar conditions. Variations in electric equipment due to different crops, farming enterprises and weather require that studies also be made in other areas.

At Beltsville a program is underway to develop and provide accurate, practical and sometimes complex instrumentation for specific program needs. Current work includes cooperation with Animal Husbandry Research Division on nondestructive measurement of fat and lean on live animals and a measure of the physiological effects of humane slaughter methods.

Federal scientific effort devoted to research in this area totals 3.5 professional man-years. Of this number 1.2 is devoted to energy distribution and farm electric demand, 1.7 to instrumentation, 0.3 to bio-electronics and 0.3 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported an estimated total of 7.5 professional man-years; of this number 7.2 devoted to instrumentation and 0.3 to electric service. The very limited amount of work on electric service is in cooperation with the power companies, which have carried most of the responsibility in this field. Research on instrumentation includes methods of measurement of fat content in living tissue, and development of instruments and apparatus for such purposes as study of stresses in soil, moisture content measurements for agricultural products, rapid determination of oil content of seeds, adaptation of strain gauge techniques to unusual measurement problems, development of partitional calorimeters, and basic analysis for agricultural aircraft equipment design.

Industry and other organizations. The continued increase in the use of electric energy has caused power suppliers to be concerned about the size of equipment such as transformers, and service entrance equipment, to supply electric service to the farm. Most of the information for equipment sizing is obtained by records of power use and equipment failure. Transformer manufacturers are reluctant to add overload indicating devices because of the expense. Estimated annual expenditures are equivalent to less than 5 professional man-years.

A number of companies are engaged in the design, development and adaptation of instruments for agricultural applications. These are mostly instruments that can be used in warehouses, processing plants, and laboratories for routine testing and measuring. Most instruments for basic farm research and farm use are of a specialized nature and quantities required are not sufficient to induce industry to conduct research or develop them. The estimated annual expenditure of research on instrumentation specifically for farm research and farm use is believed to be equivalent to approximately 5 professional man-years annually.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Energy Distribution and Farm Electric Demand. Information on the load characteristics of farms and farm equipment is required by the electric power industry to determine the sizes of farm transformers and services. Such information is also required in planning farmstead electric distribution systems and load promotion activities. Most power suppliers serving rural areas are relatively small or else farm consumers create only a small part of their total load. They are not able, therefore, to undertake load studies on a sufficient scale for the results to be meaningful. Through the cooperation of power suppliers scattered throughout the United States, data on the demands of a considerable number of farms have been obtained and are available for analysis by

the Farm Electrification Research Branch. Cooperating with ARS and power suppliers are the Iowa Experiment Station and the Rural Electrification Administration.

A method is under development for estimating the maximum demands of farms for purposes of sizing transformers. In this method the demand of a consumer is expressed in equation form with the monthly energy consumption and the appliances owned used as predictors. Data from Wisconsin, North Dakota, and Kentucky were obtained during the year for use in calculating equation coefficients. These data furnished additional evidence that the demands of farm consumers in all areas of the United States where demand peaks occur in the Winter can be estimated satisfactorily with the same set of equations. Exceptions continue to appear as more data become available indicating the necessity for demand records from the entire country.

Procedures are being developed for handling situations such as occur when both air-conditioners and electric heat are used in the same house. Another development was a procedure for combining into groups such pairs of appliances as ranges and double-oven ranges, conventional and high-speed clothes driers, and conventional and quick-recovery water heaters. Combining these pairs into single groups is necessary should the coefficient of one of a pair not be significant.

Data on the equipment required at farm yardpoles by 694 power suppliers were analyzed as a part of a study sponsored by the ASAE Farm Wiring Committee. Only half of the power suppliers were found to require overcurrent protection and disconnects. The study is being continued to develop factors which may be applied to the connected loads of farm buildings for determining the required sizes of feeders and entrance equipment.

Work on transformer loading will be continued by the analysis and reporting of data now being obtained in Alabama and Wisconsin. The wiring requirements of farms including studies of higher utilization voltages also will be investigated.

Research Instrumentation for Livestock. Ultrasonic pulse-reflection equipment provides a method for measuring, without penetration, the thickness of farm animal fat and lean tissues. Studies to improve method accuracy, and to apply the ultrasonic measurements to animal composition research were continued in cooperation with the Meat Quality Laboratory, Animal Husbandry Research Division, at Beltsville. The presence of an additional (third) fat layer at the longissimus dorsi ("loin-eye") measuring point off the midline was shown on market weight hogs. The measuring method was changed to include this layer. Measurements on pieces of hog fat of known thickness showed no significant differences due to variations in sound velocity.

New measuring points were added to provide further reliable estimates of animal meatiness. These points in hogs are at the juncture of the ham and loin, and over the 13th rib, 10, 12 and 14 inches off the mid-line. New points in cattle were at the juncture of the 13th rib and its cartilage attaching to the sternum and over the short loin, one-third the distance from the 13th rib to the pinbone.

A preliminary statistical analysis indicated that a combination of live weight and ultrasonic fat and lean measurements could be quite successful in predicting yield of hind quarter high-priced cuts of beef. (Correlation above 0.9.)

Animal holding methods and check measurement reliability need improvement before other significant factors can be studied to further increase the accuracy of the ultrasonic method. Ultrasonic pulse-reflection has shown utility as a basic research tool. However, the method is still in the development state.

Studies were conducted of relative humidity recorders (hair type) to determine probable error under poultry house constant temperature with humidity varying. Instruments were calibrated prior to and following studies in precision chamber. Instruments in new condition recorded humidity with errors less than ± 10 percent relative humidity at the calibrated temperature. At varying temperatures the error was doubled (± 20 percent relative humidity).

Bio-electronics in Animal Slaughter. In cooperation with the Meat Quality Laboratory, apparatus was assembled by AERD and techniques developed for monitoring of physiological reactions of animals during humane slaughter procedures. Based upon fundamental studies and information derived from contract studies at the University of Minnesota, procedures are being established to determine practical parameters of mechanical stunning during pilot slaughter operations.

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Instrumentation

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1961. Temperature measurement. Presented at the Winter Meeting of the American Society of Agricultural Engineers, Chicago, Illinois.

Line Project Check List -- Reporting Year April 1, 1961 to March 31, 1962

| Work & Line Project Number | Work and Line Project Titles | Work Locations During Past Year | Line Proj Summary of Progress | Incl in Area & Page no |
|----------------------------|--|--|-------------------------------|------------------------|
| AEal | Weed, insect pest, & plant disease control machinery Program leadership | Beltsville, Md. | | |
| AEal-1 | Equipment for application of pesticides, defoliant, fertilizers, & seeds from agricultural aircraft | Forest Grove, Ore. | Yes | 3-p.33 |
| AEal-3 | The development & evaluation of equipment for the control of the corn borer. | Wooster, Ohio | Yes | 3-p.25 |
| AEal-4 | Develop equipment & techniques for application of insecticides & fungicides to crops by ground machines. | Wooster, Ohio | Yes | 3-p.31 |
| AEal-5 | A study of agricultural spray patterns & droplet size & their relation to the control of crop pests | Wooster, Ohio | Yes | 3-p.24 |
| AEal-6 | Aerial spray equipment for forest insect control | Beltsville, Md. | Yes | 3-p.34 |
| AEal-11 | Equipment for the application of chemicals to the soil for control of soil pests | Wooster, Ohio | Yes | 3-p.24 |
| AEal-12 | Investigations of equipment & techniques for mechanical & chemical control of weeds in crops | Ames, Iowa; St. Paul, Minn; Columbia, Mo. | Yes | 3-p.26, 34 |
| AEal-13 | A study of basic factors which affect the behavior of pesticide particles | Wooster, Ohio | Yes | 3-p.23 |
| AEal-14 | Farm equipment requirements for improved corn production in the southeast | Experiment, Ga. | Yes <u>7/</u> | 2-p.13 |
| AEa2 | Planting & fertilizing equip. & practices Program leadership | Beltsville, Md. | | |
| AEa2-1 | Equipment & Practices for pasture & hay land establishment & maintenance | Beltsville, Md. Bushland, Tex. Athens, Ga. | Yes | 2-p.14 |
| AEa2-2 | Planting & fertilizing placement machinery for cultivated field crops & vegetable crops | Md., Va., Mich., N.Y., Ariz., Wash., and Nevada | Yes | 2-p.12, 18 |
| AEa2-4 | Equipment for applying liquid fertilizer | Beltsville, Md. E. Lansing, Mich. | Yes | 2-p.14 |
| AEa2-5 | Laboratory studies of the performance characteristics of seeding & fert. dispensing devices & equip. | Beltsville, Md. | No | |
| AEa2-7 | Develop. & improvement of production & cultural mach. for bunch and runner peanuts grown in the Virginia-Carolina Areas. | Holland, Va. | Yes <u>8/</u> | 3-p.30 |
| AE00-1 | Equipment & methods for decontamination of agricultural lands affected by radioactive fallout | Beltsville, Md. | Yes | 2-p.18 |
| AEa3 | Tillage Machinery Investigations Program leadership | Beltsville, Md. | | |
| AEa3-1 | Soil dynamics as a factor in tillage tool design | Auburn, Ala. Ames, Iowa | Yes | 1-p.4 |
| AEa3-2 | Basic studies of disk blades for agric. implements | Auburn, Ala. | Yes | 1-p.4 |
| AEa3-3 | Soil compaction by machinery | Auburn, Ala. | No | |
| AEa3-4 | Design & use of deep tillage implements | Auburn, Ala. | Yes | 1-p.3 |
| AEa3-5 | Effect of design factors on traction & transport equipment performance | Auburn, Ala. | Yes | 1-p.3 |
| AEa3-6 | Development of tillage machinery that will reduce soil erosion & runoff | Ames, Iowa | Yes | 1-p.7 |
| AEa3-7 | Measurement & characterization of physical properties of soil as related to tillage implements & tractive effort. | Auburn, Ala. | No | |
| AEa3-8 | Mathematical Relationships between forces and deformation in soil | Auburn, Ala. | Yes | 1-p.6 |
| AEb1 | Farm housing Program leadership | Beltsville, Md. | | |
| AEb1-2 | Experimental farmhouses | Athens, Ga. Beltsville, Md. | Yes | 8-p.99 13-p.159 |
| AEb2 | Livestock shelters Program leadership | Beltsville, Md. | | |
| AEb2-1 | Determination of environmental design criteria for poultry house design | Beltsville, Md. | Yes <u>5/</u> | 9-p.114 |

For footnotes see page 176

| Work & Line Project Number | Work and Line Project Titles | Work Locations During Past Year | Line Proj. Incl. in | |
|-------------------------------------|---|---|---------------------------|--------------------------------|
| | | | Summary of Progress | Area & Page no. |
| AEb2-2 | Environmental factors influencing development, production & health of dairy/beef animals under controlled conditions. | Columbia, Mo. | Yes ¹ / | 9-p.107 13-p.161 |
| AEb2-3 | Investigation of environmental factors influencing development, production & health of animals in warm climates | Davis, & El Centro, Calif. | Yes | 9-p.109, 115 13-p.161 |
| AEb2-5 | Reducing time and labor in caring for dairy animals through improved layout of buildings and yards, and the selection and adaptation of equipment | Davis, Calif. College Park, Md. St. Paul, Minn. | Yes ³ / | 9-p.105 10-p.133 |
| AEb2-7 | Livestock shelters for southeast | Tifton, Ga. | Yes ⁵ / | 9-p.109 |
| AEb2-8 | Evaluation & develop. of equip. & procedures for reducing chemical hazards assoc. with the control of livestock insects. | Kerrville, Tex. | Yes ⁵ / | 9-p.118 |
| AEb2-10 | Use of models for analyzing farmstead layouts | St. Paul, Minn. | Yes ^{5,9} / | 9-p.106 |
| AEb2-11 | Time standards for farmstead work elements | St. Paul, Minn. | Yes ^{5,9} / | 10-p.133 9-p.105 |
| AEb2-13 | Development of prototype environmental cabinet for poultry disease research | Athens, Ga. | Yes ⁵ / | 9-p.115 |
| AEb3 | Storages & related equipment for farm products Program leadership | Beltsville, Md. | | |
| AEb3-10 | Studies of basic factors in design & operation of silos | Beltsville, Md. | Yes | 7-p.92 |
| AEb3-11 | Development of improved methods, equip. & structures for making, storing & feeding silage in S.E. | Athens, Ga. Watkinsville, Ga. | Yes | 7-p.93 |
| AEb3-12 | Farm storage of high moisture grain | Athens, Ga. & Ames, Iowa | Yes | 7-p.95 |
| AEb3-14 | Pressures of wheat & soybeans on bin walls, floors and structural members | Ames, Iowa | No | |
| AEb4 | Farm Building Plan exchange & information Program leadership | Beltsville, Md. | | |
| AEb4-5 | Farmhouse plans & information | Beltsville, Md. | Yes | 8-p.100 7-p.95 |
| AEb4-6 | Farm Service Building Plans and Information | Beltsville, Md. | Yes | 9-p.109, 111 113, 115 |
| AEb5- | Materials & construction methods for farm buildings Program leadership | Beltsville, Md. | | |
| AEb5-4 | Evaluation of stabilized earth blocks made under high pressure as a farm building material | Beltsville, Md. | Yes | 10-p.131 |
| AEb5-5 | Development & evaluation of Portland cement-sand sandwich panels | Blacksburg, Va. | Yes ¹ / | 10-p.131 |
| AEb5-6 | Incorporation & application of hyperbolic paraboloid (HP theory to the struct. use of sheet materials in farm structure roof design | Beltsville, Md. | Yes ³ / | 10-p.131 |
| AEb5-7 | Evaluation of rotational resistance of nailed joints to be used in farm structures | Blacksburg, Va. | Yes ⁵ / | 10-p.132 |
| AEb5-9 | Influence of housing structures & equip. on air-sacculitis & condemnations of broilers | State College, Miss. | Yes ⁵ / | 9-p.115 10-p.132 |
| AEb6 | Farmstead water supply & wastes disposal Program leadership | Beltsville, Md. | | |
| AEb6-2 | Farmstead water requirements | College Park, Md. | Yes | 10-p.132 |
| AEc1 | Cotton ginning investigations Program leadership | Beltsville, Md. | | |
| AEc1-10 | Gin waste collection and disposal | Mesilla Pk, N.M. Stoneville, Miss. Clemson, S.C. | Yes Yes No | 6-p.85 6-p.85 |
| AEc1-13 | Seed cotton handling and storage | Clemson, S.C. Stoneville, Miss. | Yes ² / Yes | 6-p.76 6-p.76 |
| AEc1-14 | Measuring elements of fiber quality as affected by ginning & assoc. operations | Stoneville, Miss. Mesilla Pk, Miss. Clemson, S.C. | Yes Yes Yes | 6-p.82, 85 6-p.82 6-p.77 |
| AEc1-15 | Moisture content of cotton for optimum gin house operation | Stoneville, Miss. Mesilla Pk, N.M. Clemson, S.C. | Yes Yes Yes | 6-p.79 6-p.79 6-p.77, 79 |
| AEc1-16 | Removing grass and green leaf fragment from cotton | Stoneville, Miss. Clemson, S.C. | Yes ⁴ / Yes | 6-p.79 6-p.79 |

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| AEcl-17 | Cleaning and drying cottonseed concurrently with ginning | Stoneville, Miss. | Yes ^{4/} | 6-p.85 |
| AEcl-19 | Testing improved ginning equipment and adopting it to different locations in the Cotton Belt | Clemson, S.C. Stoneville, Miss. Mesilla Pk, N.M. | Yes ^{4/} Yes No | 6-p.79 6-p.84 |
| AEcl-20 | Developing new principles for separating cotton fiber | Clemson, S.C. Stoneville, Miss. Mesilla Pk, N.M. | No ^{4/} No No | |
| AEcl-22 | Evaluating cotton bale packaging materials and ties | Stoneville, Miss. Mesilla Pk, N.M. | No ^{4/} No | |
| AEcl-23 | Improvement of mach. & equip. for ginning extra long staple cotton | Mesilla Pk, N.M. | Yes | 6-p.81 |
| AEcl-24 | Fundamental mechanisms of nep formation in cotton | Mesilla Pk, N.M. | No | |
| AEcl-25 | Sorting & grouping cotton fiber by length for test purposes at gins. | Stoneville, Miss. Mesilla Pk, N.M. Clemson, S.C. | Yes Yes No | 6-p.82 6-p.82 |
| AEcl-26 | Developing apparatus for obtaining a representative sample of fiber in conjunction with ginning | Stoneville, Miss. Mesilla Pk, N.M. | No ^{4/} No | |
| AEcl-27 | Improving saw gins | Stoneville, Miss. Mesilla Pk, N.M. Clemson, S.C. | Yes No No | 6-p.81 |
| AEcl-28 | Reducing the degrading effects of weathering in the field & the action of insects & microorganisms on ginned cotton fiber & seed | Clemson, S.C. | Yes | 6-p.80 |
| AEcl-29 | Investigations of the causes for changes in fiber properties resulting from conditioning treatments of cotton before cleaning & ginning | Stoneville, Miss. | Yes | 6-p.76 |
| AEcl-30 | Investigation of fiber quality problems related to changes in production & harvesting practices as revealed thru ginning | Clemson, S.C. Stoneville, Miss. Mesilla Pk, N.M. | Yes Yes Yes | 6-p.76 6-p.83 6-p.83 |
| AEcl-31 | Cotton ginning efficiency and cost | Stoneville, Miss. | Yes ^{1/} | 6-p.81 |
| AEcl-32 | Development of alternative seed cotton cleaning devices & methods based on a thorough evaluation of present equipment | Stoneville, Miss. Chickasha, Okla. | Yes ^{3/} Yes | 6-p.79 6-p.80 |
| AEcl-33 | Improvement & evaluation of equipment for cleaning lint cotton. | Stoneville, Miss. | Yes ^{3/} | 6-p.84 |
| AEc2 | Long vegetable fiber engineering investigations Program leadership | Beltsville, Md. | | |
| AEc2-2 | Improving processes & techniques for cleaning ramie ribbons | Belle Glade, Fla. | Yes | 4-p.53 5-p.70 |
| AEc2-5 | Bast fibers quality testing instruments and techniques | Belle Glade, Fla. | No ^{4/} | |
| AEc2-6 | Developing brush bristle fiber decorticating equipment and methods | Belle Glade, Fla. | Yes | 5-p.70 |
| AEc2-7 | Developing harvesting & farm handling equip. for bamboo | Belle Glade, Fla. | Yes | 4-p.54 |
| AEc2-8 | Sansevieria harvesting, defiberizing, & fiber conditioning machinery & methods | Belle Glade, Fla. | Yes | 4-p.54 |
| AEc2-9 | Development of improved harvesting & processing mach. & methods for the prod. of kenaf & other jute like fibers. | Belle Glade, Fla. | Yes | 4-p.54 5-p.70 |
| AEc3 | Equip. for harvesting & farm handling of fruits & vegetables. Program leadership | Beltsville, Md. | | |
| AEc3-9 | Equip. & methods for harvesting apples | Wenatchee, Wash. E. Lansing, Mich. | Yes Yes | 4-p.47 4-p.48 |
| AEc3-10 | Equipment and methods for handling tree fruits in bulk | Wenatchee, Wash. E. Lansing, Mich. | Yes ^{4/} Yes | 4-p.48 4-p.48 |
| AEc3-11 | Equip. & methods for harv. & farm handling & pack. of cultivated blueberries | E. Lansing, Mich. | Yes | 4-p.48 |
| AEc3-12 | Equip. & methods for harvesting cherries | E. Lansing, Mich. | Yes | 4-p.49 |

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| AEc3-13 | Equip. & methods for handling & harv. concord grapes | E.Lansing, Mich | Yes | 4-p.49 |
| AEc3-14 | Pre-harvesting practices for increasing the efficiency of mechanized potato harvesting | E.Grand Forks, Minn. | Yes | 4-p.57 |
| AEc3-15 | Equip. & methods for increasing the recovery of potatoes that are harv. mechanically | E.Grand Forks, Minn. | Yes | 4-p.58 |
| AEc3-16 | Equip. & methods for harv. & orch. handling of prunes that are to be dried | Davis, Calif. | Yes | 4-p.50 |
| AEc3-17 | Equipment and methods for harvesting and orchard handling of edible tree nuts, olives, & figs | Davis, Calif. | No <u>4</u> / | |
| AEc3-18 | Equipment and methods for field bulk box filling and handling of potatoes | E.Grand Forks, Minn. | No <u>2</u> / | |
| AEc3-19 | The development of an automatic equilizing six piece seed potato cutter | E.Grand Forks, Minn. | No <u>4</u> / | |
| AEc3-20 | Equip.& methods for mech. harvesting cling-stone & freestone peaches & apricots | Davis, Calif. | Yes | 4-p.50 |
| AEc3-21 | Mech. injury of potatoes-evaluation, causes & prevention | E.Grand Forks, Minn. | Yes <u>3</u> / | 4-p.58 |
| AEc3-22 | Equip.& methods for thinning peaches & apples mechanically | E.Lansing, Mich. | Yes <u>3</u> / | 4-p.51 |
| AEc3-23 | Engineering cost study of harv. potatoes Mechanically | E.Gr.Fork, Minn. | Yes <u>3</u> / | 4-p.58 |
| AEc3-24 | Equip. & methods for harv. dates mechanically | Davis, Calif. | Yes <u>3</u> / | 4-p.51 |
| AEc4 | Farm seed cleaning & handling Program leadership | Beltsville, Md. | | |
| AEc4-3 | Seed conveying and handling methods and machinery | Corvallis, Ore. | Yes <u>4</u> / | 5-p.67 |
| AEc4-4 | Seed cleaning research applied to specific problem mixtures | Corvallis, Ore. | Yes | 5-p.67 |
| AEc4-6 | Cutting & feeding mechanisms for legume & grass seed crop harvesting equipment | Clemson, S.C. | Yes | 4-p.52 |
| AEc4-7 | Improved techniques for harvesting seed crops | Corvallis, Ore. | Yes | 4-p.13 |
| AEc4-8 | Development of a centrifugal-pneumatic seed separator | Clemson, S.C. | Yes | 4-p.13 |
| AEc4-9 | Electrostatic seed separation | Corvallis, Ore. | No | |
| AEc4-10 | Optimum moisture content for seed harvesting | Corvallis, Ore. | Yes | 11-p.143 |
| AEc4-11 | Modification of seed-length separators | Corvallis, Ore. | Yes | 4-p.53 |
| AEc4-12 | Development of vibratory feeders for seeds | Corvallis, Ore. | Yes | 5-p.68 |
| AEc5 | Equipment for mech. cotton prod.-Program leadership | Corvallis, Ore. | Yes <u>3</u> / | 5-p.68 |
| AEc5-1 | Develop. of equipment & techniques for cotton planting fertilizing & crop residue disposal, & seedbed preparation | Beltsville, Md. | | |
| | | Auburn, Ala. | Yes | 2-p.17 |
| | | Shafter, Calif. | Yes | 2-p.15 |
| | | Stoneville, Miss. | Yes | 2-p.15 |
| | | Chickasha, Okla. | No | |
| | | Lubbock, Tex. | Yes | 2-p.17 |
| AEc5-2 | Development of mach. for chemical & mechanical control of cotton pests (weeds, insects, diseases) | Auburn, Ala. | Yes | 2-p.17 |
| | | Shafter, Calif. | Yes | 3-p.29 |
| | | Stoneville, Miss. | Yes | 3-p.28 |
| | | Chickasha, Okla. | No | |
| | | Lubbock, Tex. | Yes | 3-p.29 |
| AEc5-3 | Development & evaluation of machines & methods for mechanical harvesting of cotton | Auburn, Ala. | Yes | 4-p.42 |
| | | Shafter, Calif. | Yes | 4-p.42 |
| | | Stoneville, Miss. | Yes | 4-p.43 |
| | | Chickasha, Okla. | Yes | 4-p.46 |
| | | Lubbock, Tex. | Yes | 4-p.43 |
| AEc5-4 | Equip. & techniques for crop residue disposal in cotton production | Stoneville, Miss. | No <u>3</u> / | |
| AEc5-5 | Equip. & methods for optimum seedbed preparation for cotton | Stoneville, Miss. | | |
| | | Shafter, Calif. | No <u>3</u> / | |

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| AEc5-6 | Power requirements of cotton prod. implements | Stoneville, Miss. | No ^{3/} | |
| AEc5-7 | Synthetic mulches for improving cotton stands | Shafter, Calif. | No ^{3/} | |
| AEc6 | Grain harvesting & conditioning- Program leadership | Stoneville, Miss. | No ^{3/} | |
| AEc6-9 | Harvesting efficiency as affected by cutting tops from corn | Lubbock, Tex. | No | |
| AEc6-10 | Effects of heated air drying on grain quality | Beltsville, Md. | No | |
| AEc6-11 | Moisture relations in grains as they effect drier design | Ames, Iowa | Yes | 5-p.71 |
| AEc6-12 | Studies of the drying zone in mechanical grain driers | Ames, Iowa | Yes | 5-p.71 |
| AEc6-13 | The relationship of wet bulb temperature to grain dryer design and use | Ames, Iowa | Yes ^{6/} | 5-p.70 |
| AEc6-14 | Mechanical damage to corn during harvesting and handling | Experiment, Ga. | Yes | 4-p.53 |
| AEc6-15 | Permissible time for drying grain using unheated air | Ames, Iowa | No | |
| AEc7- | Specialized crop production & harvesting machinery | Ames, Iowa | Yes | 5-p.71 |
| AEc7-5 | Develop. & Evaluation of new forage harv. equip. and methods | Program leadership | | |
| AEc7-8 | Develop. & improvement of peanut diggers & shakers | Beltsville, Md. | Yes | 4-p.51 |
| AEc7-9 | Develop. & improvement of tung harvesters & wind-rowers for optimum effectiveness & efficiency | Beltsville, Md. | Yes | 5-p.72 |
| AEc7-10 | Develop. & improvement of equip. & methods of handling tung fruit to storage on farm & to processing mill. | Holland, Va. | Yes | 4-p.57 |
| AEc7-11 | Determine engr. requirements for artificially conditioning tung fruit for good storage; & to develop an efficient portable huller | Bogalusa, La. | Yes | 4-p.54 |
| AEc7-13 | Develop. & improvement of peanut harvesting & field handling equipment | Bogalusa, La. | Yes | 4-p.55 |
| AEc7-14 | Development of improved castor bean production, harv., hulling & conveying equipment | Bogalusa, La. | Yes | 5-p.72 |
| AEc7-15 | Development of a cutter, cleaner, loader type of sugarcane harvester | Holland, Va. | Yes | 4-p.57 |
| AEc7-16 | Engineering studies of factors related to harv. & farm processing coastal Bermudagrass | Stillwater, Okla. | Yes | 4-p.55 |
| AEc7-17 | Mechanical harvesting Burley tobacco | Houma, La. | Yes | 4-p.58 |
| AEc7-18 | Curing Burley Tobacco | Tifton, Ga. | Yes ^{3/} | 4-p.51 |
| AEd2 | Automatic electric controls for farm equipment | Lexington, Ky. | Yes ^{5/} | 5-p.72 |
| AEd2-1 | Automatic electric controls for farm equipment | Lexington, Ky. | Yes ^{5/} | 4-p.60 |
| AEd2-2 | Develop. of elec. and other labor-saving & honey-conditioning equip. for apiary operation in North Central states | Beltsville, Md. | Yes | 5-p.69 |
| AEd2-4 | Develop. of elec. and other labor-saving & honey-conditioning equip. for apiary manipulation in S.W. | Madison, Wisconsin | Yes | 12-p.150 |
| AEd2-5 | Development of electrical equipment for cage laying hens. | Tucson, Arizona | Yes | 12-p.151 |
| AEd2-6 | Automatic elec. control systems for livestock production | Lafayette, Ind. | No ^{2/} | |
| AEd3 | Electric equip. for removing & handling silage from horizontal silos | Urbana, Ill. | Yes | 12-p.149,152 |
| AEd3-1 | Elec. equip. for environmental modification and control in farm living & production-Program leadership | Pullman, Wash. | Yes ^{10/} | 12-p.150 |
| AEd3-1 | Improved methods and equipment used for curing dark-fired and air-cured tobaccos. | Beltsville, Md. | Yes ^{6/} | 13-p.162 |

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| AEd3-2 | Evaluation of electric equipment for reducing pig losses | Lafayette, Ind. | No | |
| AEd3-3 | Study of heat pump for air-conditioning of farm homes and other farm buildings | Manhattan, Kans. | Yes | 13-p.158 |
| AEd3-4 | Electrical equipment for cooling and heating poultry houses. | Athens, Ga. | Yes ^{4/} | 13-p.160 |
| AEd3-5 | Equip. systems for controlling light & temp. for turkey breeding stock | Beltsville, Md. | Yes | 13-p.159 |
| AEd3-6 | Development of electrical and other equipment for curing bright-leaf tobacco. | Raleigh, N.C. | Yes ^{6/} | 13-p.162 |
| AEd3-7 | Elec. equip. for efficient hog production (including heat pump for cooling & heating hog houses) | Holland, Va. | Yes ^{3/} | 13-p.160 |
| AEd3-8 | Design factors for electrically controlled air flow & ventilation equip. in broiler houses | Athens, Ga. | Yes ^{3/} | 13-p.160 |
| AEd3-9 | Relation & control of carbon dioxide & light & effects on plants in air supported plastic greenhouses | Pullman, Wash. | Yes ^{3/} | 13-p.157 |
| AEd4 | Application of electromagnetic radiation to plants animals, & their products & to insects and soils Program leadership | Beltsville, Md. | | |
| AEd4-1 | Develop. of equip. for attracting & destroying economic insects with elec. energy in North Central states | Lafayette, Ind. | Yes | 11-p.138,139,140 |
| AEd4-2 | Use of radio frequency energy for insect control & conditioning of farm products | Lincoln, Neb. | Yes | 11-p.141,143 |
| AEd4-3 | Developing of elec. equip. for attracting and/or destroying economic insects in the S.W. states | Coll. Station, Texas | Yes | 11-p.138 |
| AEd4-4 | Develop. of electromagnetic radiation equipment for seed & plant product treatment | Knoxville, Tenn. Pullman, Wash. | Yes Yes | 11-p.142,143 |
| AEd4-5 | Develop. of equip. for attracting, repelling and/or destroying economic insects with physical stimuli in southeastern states | Blacksburg, Va. | Yes ^{11/} | 11-p.139 |
| AEd4-6 | Evaluation & develop. of equip. & phy. methods for control of flies & other livestock pests | Beltsville, Md. | No ^{3/} | |
| AEd5 | Farm electric equip. performance & requirements & farm elec. energy distribution. Program leadership | Beltsville, Md. | | |
| AEd5-1 | Determination of electric demand characteristics of farm equipment | Ames, Iowa | Yes | 14-p.167 |
| AEd5-2 | Electric chick brooder performance evaluation and design improvement. | Athens, Ga. | No ^{4/} | |
| AEd5-3 | Electric milk cooling & handling equip. performance requirements | Beltsville, Md. | No ^{1/} | |
| AEd5-4 | Performance tests of unloaders for vertical silos | St. Paul, Minn. | Yes ^{3/} | 12-p.150 |
| AEd5-5 | The use of 480 volts for distribution & use of elec. energy for farm use | St. Paul, Minn. | No ^{3/} | |
| AEd6 | Development of technical instruments & measurement techniques for farm production & related electrification research Program leadership | Beltsville, Md. | | |
| AEd6-1 | Equipment for non-destructive measurement of fat & lean on live animals. | | Yes ^{1/} | 14-p.168 |

1/ Initiated 1960
2/ Terminated 1960
3/ Initiated 1961
4/ Terminated 1961

5/ Initiated 1962
6/ Terminated 1962
7/ Supersedes AEd6-14
8/ Supersedes AEd7-12

9/ Supersedes AEd2-5
10/ Supersedes AEd2-3
11/ Supersedes AEd1-15